MEMORANDUM REPORT BRL-MR-3707

BRL

1938 – Serving the Army for Fifty Years – 1988

INITIAL YAWSONDE TESTS OF 155MM M864 BASE-BURN PROJECTILE

VURAL OSKAY
JAMES M. GARNER

NOVEMBER 1988

U.S. ARMY LABORATORY COMMAND

BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) BRL-MR-3707	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Ballistic Research Laboratory; 6b. OFFICE SYMBOL (If applicable) SLCBR-LF	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Aberdeen Proving Ground, MD 21005-5066	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION U.S. Army Ballistic Research Laboratory; 8b. OFFICE SYMBOL (If applicable) SLCBR-DD-T	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Aberdeen Proving Ground, MD 21005-5066	10. SOURCE OF FUNDING NUMBERS: PROGRAM ELEMENT NO. 62618A; PROJECT NO. 1L1 62618AH80; TASK NO. N/A; WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Initial Yawsonde Tests of 155mm M864 Base-Burn Projectile

12. PERSONAL AUTHOR(S)
Oskay, Vural; Garner, James M.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Memorandum Report	FROM ______ TO ______	1988 August	39

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Yawsonde
01	01		Flight Dynamics
19	06		Base-Burn Projectile

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Twelve yawsonde-instrumented, 155mm M864 base-burn projectiles were tested at Yuma Proving Ground, Arizona, to determine the effects of muzzle velocity and quadrant elevation on flight performance. Of particular interest were the flight data near burn-out of the base-burn grain at approximately 30 seconds. Yawsonde results indicated no unusual effects at burn-out on either the yaw or the spin histories of the M864 projectiles.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED	
22a. NAME OF RESPONSIBLE INDIVIDUAL Vural Oskay	22b. TELEPHONE (Include Area Code) (301)-278-2849	22c. OFFICE SYMBOL SLCBR-LF-A

Table of Contents

List of Figures

List of Tables

I. Introduction

Yawsonde tests are normally conducted during the development phase of projectile testing. An initial attempt to conduct the test was made during late 1985 as part of an accuracy test program (sponsored by the Armament Development and Engineering Center (ARDEC)) at Yuma Proving Ground (YPG), Arizona. A single round was tested to impact. However, the projectile did not contain a spotting charge to enhance the probability of locating the impact point. Damp soil conditions from the previous day's rain precluded the observation of impact. Only one test day was allocated for the yawsonde firings; hence, the test program was aborted.

Since then, both the projectile and its base-burn motor grain have gone through modifications to improve system performance. By the time the next yawsonde test series was scheduled, a large volume of firing data existed. Therefore, it was decided that the yawsonde firings would be used to supplement the existing test data. Based upon test conditions specified in Reference 1, twelve(12) M864 projectiles were fired at two QE's with three muzzle velocities. The test matrix is given in Table 1. The purpose of this program was to examine the flight behavior at motor burn-out as a function of velocity and altitude. Since the base-burn motor significantly modifies the base drag, then it could also impact the flight dynamics of the projectile near the motor burn-out. This report presents the results of the yawsonde program.

II. Test Program and Instrumentation

During the scheduling of this program, several delays were encountered due to various YPG test priorities and hardware delivery difficulties. When the program was finally scheduled, only three days were allocated. One of those three days was used to set up the required instrumentation. As a result, only two days were available to fire the yawsonde program. However, it was decided to reserve one day for contingencies and test all rounds in one day. Therefore, several of the rounds were fired under non-optimal weather conditions, which caused portions of the flight data to be lost for five high quadrant-elevation rounds.

All test projectiles were instrumented with Ballistic Research Laboratory (BRL) constructed fuze-type yawsondes[2]. A yawsonde is an electro-optical device designed to determine the in-flight behavior of an artillery projectile. It is configured to replace a standard artillery fuze. The yawsonde contains two silicon solar cells, a signal conditioning circuit, a transmitter, and a spin-activated power supply. When a silicon cell is exposed to the sunlight, it will generate a DC voltage that is used to modulate a subcarrier oscillator that feeds an RF transmiter. Voltages from both silicon cells are combined to generate an analog signal whose phase is related to the shell's angle with respect to the sun. The transmitted signal is received on the ground and demodulated to remove the carrier frequency. The resulting subcarrier signal is recorded on analog tape for later analysis. The subcarrier

[1] Test Program Request (TPR) (LCU-S-2973) Revision 1 to Amend. 2, Supl. 6 for Projectile, 155mm: Extended Range, DP, XM864 (TECOM Project No. 2-MU-003- 864-003), ARDEC, Dover, New Jersey, 13 May 1987

[2] Mermagen, W. H. and Clay, W. H., "The Design of a Second Generation Yawsonde," MR-2368, U. S. Army Ballistic Research Laboratory, APG, MD, April 1974. (AD 780064)

is discriminated to reproduce the original raw yawsonde pulse train. These pulse data can be related to the Eulerian roll rate, $\dot{\phi}$, which at small yaw angles closely approximates the spin, and the complementary solar angle, σ_n, which yields yaw data through the individual calibration of that yawsonde obtained during its manufacture.[3] The angle, σ_n , is defined as the angle between the normal to the projectile's spin axis and a line to the sun from the projectile's center of mass. The value of σ_n depends on the sun's location (test site, time of the year, time of the day), the line of fire, the trajectory angle, and the local value of the shell's yaw.

The yawsonde data were acquired by Harry Diamond Laboratory (HDL) personnel using their instrumentation van. Two helical antennas were used, and the output of each antenna was fed into a separate P-band receiver through a pre-amplifier. The video signals were then recorded on an analog tape for subsequent analysis. The receiving station was located 500 meters behind the gun and about 15 degrees to the right of line of fire. Muzzle velocities were measured by doppler velocimeters. Two Hawk doppler radars covered the full trajectory. The maximum range of the Hawk is about 15 kilometers. Hence, one radar was placed behind the gun at the test site, while a second radar was located down range to acquire the incoming shell and to track it to impact. However, the second radar did not track any of the rounds. In addition to the Hawk radars, the ARBAT (Applications of Radar to Ballistic Acceptance Testing) radar was used in both a position tracking and a doppler mode. The projectile impact points reported here were determined by four observation stations that were moved to appropriate locations according to the estimated impact points.

III. Test Results

Results of the test program will be discussed under two headings: real-time observer data and yawsonde reductions. The real-time observer data will give the test conditions, shell related information, muzzle velocities, and impact points. The yawsonde reductions will be plots of σ_n and $\dot{\phi}$ as functions of flight time for each test projectile.

1. Real-Time Observer Data

As indicated in Table 1, the test program consisted of two QE's and three muzzle velocities. These conditions were selected to match some of the previous developmental tests. However, the requirements for the yawsonde operations necessitated modification of the firing order from the one shown in Table 1. It was possible to start the low QE tests after 1000 hours whereas, the high QE rounds could not be fired before 1300 hours. Table 2 lists tube round number, projectile type, yawsonde number, muzzle velocity, impact range, and other relevant details for each round in the order of launch. Some of the delays during the test were required so that the observers could be moved to different observation sites, while additional delays were encountered near the end of the firing program when

[3] Clay, W. H., "A Precision Yawsonde Calibration Technique", MR 2263, U. S. Army Ballistic Research Laboratory, APG, MD, January 1973. (AD 758158)

clouds partially obscured the sun. Although the impact data must be corrected for muzzle velocity and meteorological conditions, the preliminary impact data did not indicate any unexpected flight behavior.

2. Initial Yawsonde Observations

Initial observations from the yawsonde tests of M864 projectile are listed in Table 3. Changes in line of fire, observer movements, and variations in the weather conditions are especially important and affect the timing and the clarity of the yawsonde data.

3. Yawsonde Reductions

The reduced yawsonde data will be discussed in sections 4 and 5. They are presented in terms of "yaw angle" (σ_n) and "spin rate" ($\dot{\phi}$) in the projectile-sun system. The character of the σ_n data is determined by the yawing motion, the sun's position with respect to the line of fire, and the trajectory of the test item. However, in spite of these complications, the basic features of the yawing behavior are faithfully represented by the σ_n versus time plots. The peak-to-peak excursions of σ_n represent the total angular motion about the trajectory. Since the projectile is traveling on an earth fixed coordinate system rather than a shell fixed system, the "spin" measured by the yawsonde, is the rate of change of the Euler angle of the shell. Therefore, under conditions of large yaw, the plot of $\dot{\phi}$ versus time will show modulations which are not really spin variations.[4] However, the average of these oscillations closely approximates the actual spin history of the shell along its trajectory.

4. Yaw Angle Versus Time

Plots of σ_n versus time for the M864 shell are presented in Figures 1 through 12. Rounds 4258 and 4259 were fired with M119A2 propellant at a QE of 355 mils (20 degrees) and had live base-burn units. Both projectiles showed very small initial yaws which quickly damped (see Figures 1 and 2a). At the beginning of Figure 2a, there seemed to be a change in the yaw level; a close scrutiny of that region (Figure 2b) indicated that the observed level change was due to signal irregularity and not a change in the yawing behavior of the shell. Note that on both sides of the step, the same yaw level was visible. However, the data from both rounds gave indications of RF interference between 25 and 30 seconds, where the base-burn grain is near extinguishment. The source of the poor signal to noise ratio is unknown.

One of the three projectiles fired with the M203A1 charge at a QE of 355 mils had an inert base-burn unit. Both of the live base projectiles showed about 2 degrees of yaw early in their flight; but this yaw quickly damped (see Figures 3 and 4a). These flight data also exhibited noise in the region of 30 to 35 seconds into the flight. Finally, they gave an

[4] Murphy, C. H. , "Effects of Large High-Frequency Angular Motion of a Shell on the Analysis of Its Yawsonde Records", ARBRL-MR-2581, U. S. Army Ballistic Research Laboratory, APG, MD, February 1976. (AD 0094210)

indication of a small slow-mode limit cycle near impact. The early part of Figure 4a showed some sizeable motion. Again, after closer scrutiny (see Figure 4b), it was obvious that the apparent motion was really noise in the reduced data due to signal form irregularities. The yawing motion of the inert base-burn round (Round 4262) is plotted in Figure 5. Very little motion was evident early in the flight, but some indication of a slow mode limit cycle was seen near impact. Again, there was signal noise in the time frame between 20 and 35 seconds, indicating that under this flight condition the receiving antenna was probably looking at the null of the transmitting antenna.

The next seven rounds were fired at QE of 1150 mils (64.5 degrees). Their yawing behaviors are shown in Figures 6 through 12. The first three rounds (Figures 6, 7, and 8) were fired with the M203A1 charge. Rounds 4271 and 4272 had live base-burn motors, while Round 4273 had an inert one. Figure 6, Round 4271, showed a small amplitude yawing motion that was dominated by the slow precessional mode. This motion was damped by 25 seconds, however. Unfortunately, due to poor sun conditions, there were no comparable early data for the next two flights (Figures 7 and 8). Rounds 4274 and 4275 were fired with M119A2 charge. They both had live base-burn motors. As before, the data in Figure 9 (Round 4274) showed a small amplitude, slow precessional mode motion early in the flight. The shift in the mean yaw level was produced by the effects of background sunlight conditions on the video signal quality. Although there were no early data for the yawing behavior of Round 4275, Figure 10 does not provide any reason to believe that the behavior was different from that of the previous round. The final two rounds were fired with M4A2 Zone 7 charge (one live and one inert base-burn unit). Data are shown in Figures 11 and 12 and do not indicate any unexpected behavior. The larger amplitude slow precessional mode motion of Round 4277 (around 20 seconds) could be due to the wind effects rather than any major aerodynamic difference between the inert and live rounds.

5. Roll Rate Versus Time

Plots of $\dot{\phi}$ are given in Figures 13 through 24 as a function of flight time. Some of the $\dot{\phi}$ data (Figures 17, 19, 20, 22, 23, and 24) were not obtained from the yawsonde pulse data due to signal distortions. Hazy sky conditions produce two undesireable effects: (1) pulse shapes that do not have sharp leading edges and (2) baseline voltages (the signal level away from base of the pulses) that are non-zero. However, the basic pulse ensemble (a group of three pulses, positive, negative, and positive) and the associated baseline still contain information from which the the roll period can be extracted. The raw analog yawsonde voltage can, therefore, be processed by a spectrum analyzer (SA) to extract the roll period. The resolution and data density of SA-obtained roll data are far less than those of a standard yawsonde reduction. The SA data are digitally filtered, but residual perturbations are still present. These perturbations are an artifact of the SA method and do not reflect unusual roll behavior by the projectile.

Figures 13 and 14 show the spin histories of the two live rounds fired with M119A2 charge at a QE of 355 mils (20 degrees). A comparison of the data in these figures indicates consistent performance with no unexpected spin behavior near burn-out, which should have occurred at about 30 seconds. Spin data from the projectiles fired with the

M203A1 charge are shown in Figures 15, 16, and 17. Rounds 4260 and 4261 also showed consistent behavior with no undue spin changes near burn-out. Round 4262 had an inert motor and also showed a normal spin decay.

Figures 18 through 24 show the spin histories of the M864 projectiles fired at a QE of 1150 mils (64.5 degrees). Data in Figures 18 and 21 were obtained from the yaw reduction and, thus, terminate at about 50 seconds when the trajectory parameters and sunlight conditions limit the yaw data. Figures 18 and 19 give $\dot{\phi}$ as a function of time for the two live rounds fired with the M203A1 charge. Figure 19 only provides data beyond 35 seconds since the raw signals were very poor and even the SA process returned valid data beyond that time. The spin data for the inert M864 shell fired with the M203A1 charge are shown in Figure 20. There were no spin anomalies for this round. Spin histories for the two live-motor projectiles fired with M119A2 charge are shown in Figures 21 and 22. The data were consistent with no unexpected behavior. Finally, Figures 23 and 24 show the spin histories of the two projectiles fired with the M4A2 Zone 7 charge. The spin histories of the live and inert projectiles were very similar with the exception of a variation on the down leg of their trajectories due to different velocity histories of the shell.

IV. Conclusions

Yawsonde and impact data were presented and discussed for supersonic launch conditions. These data do not indicate any unexpected behavior nor do they show any difference in aeroballistic behavior between live and inert base-burn shell. Although increased RF noise was observed between 25 and 30 seconds for most of the projectiles, there were no observable changes in the dynamic behavior of the live-motor projectile in the region of burn-out. During this test series, projectiles were only fired at the three top zones where the flight performance of the shell is typically adequate. No transonic/induced-yaw launch conditions were tested. On the other hand, if other cargo or payload concepts are to be utilized (such as liquid or potentially loose internal parts payloads), then more complete tests should be conducted to assure proper flight performance.

Table 1. M864 Yawsonde Test Matrix, May 1987

Propelling Charge	Base Burn Grain	Quantity Fired	Quadrant Elevation (mils)	Velocity (M/SEC)
M203A1	Live	2	1150	805
M203A1	Inert	1	1150	805
M203A1	Live	2	355	805
M203A1	Inert	1	355	805
M119A2	Live	2	1150	675
M119A2	Live	2	355	675
M4A2(Z7)	Live	1	1150	550
M4A2(Z7)	Inert	1	1150	550

Table 2. Round-by-Round Data for M864 Yawsonde Test Firings

ROUND NO	BASE BURN	SHELL NO	YAWSONDE NO	CHARGE	QE (MILS)	TIME OF FIRE(MST)	MUZZLE VEL(M/S)	RANGE (M)
4258	LIVE	Y- 5	2242	M119A2	355	1008	675.7	16718
4259	LIVE	Y- 6	2243	M119A2	355	1014	679.4	16716
4260	LIVE	Y-11	2244	M203A1	355	1052	807.6	21138
4261	LIVE	Y-12	2245	M203A1	355	1058	805.4	21109
4262	INERT	Y- 3	2246	M203A1	355	1103	802.6	18290
4271	LIVE	Y- 9	2247	M203A1	1150	1304	803.4	24590
4272	LIVE	Y-10	2248	M203A1	1150	1312	804.4	24838
4273	INERT	Y- 2	2249	M203A1	1150	1347	804.7	20160
4274	LIVE	Y- 7	2250	M119A2	1150	1407	676.9	18669
4275	LIVE	Y- 8	2251	M119A2	1150	1425	673.1	18565
4276	LIVE	Y- 4	2252	M4A2(Z7)	1150	1448	552.4	14196
4277	INERT	Y- 1	2253	M4A2(Z7)	1150	1457	547.9	12080

Table 3. Preliminary Observations During Yawsonde Firings of M864

ROUND NO	YAWSONDE NO	QE (MILS)	AZIMUTH FROM NORTH (DEG:MIN)	TIME OF FIRE (MST)	REMARKS
4258	2242	355	75:50	1008	Clean signal to impact
4259	2243	355	75:50	1014	Clean signal to impact
4260	2244	355	75:50	1052	Moved observers; clean signal to impact
4261	2245	355	75:50	1058	Clean signal to impact
4262	2246	355	75:50	1103	Clean signal to impact
4271	2247	1150	73:30	1304	Moved observers; good signal within window
4272	2248	1150	73:30	1312	Partial clouds; some signal modulation at start; good signal within window
4273	2249	1150	73:30	1347	Moved observers; good signal within window
4274	2250	1150	74:00	1407	10-minute hold for clouds; good signal within window
4275	2251	1150	74:00	1425	9-minute hold for clouds; good signal within window
4276	2252	1150	74:00	1448	19-minute hold for clouds; moved observers; some signal modulation at start; good signal within window
4277	2253	1150	74:00	1457	5-minute hold for clouds; signal amplitude modulations during the first 10 minutes; good signal within window

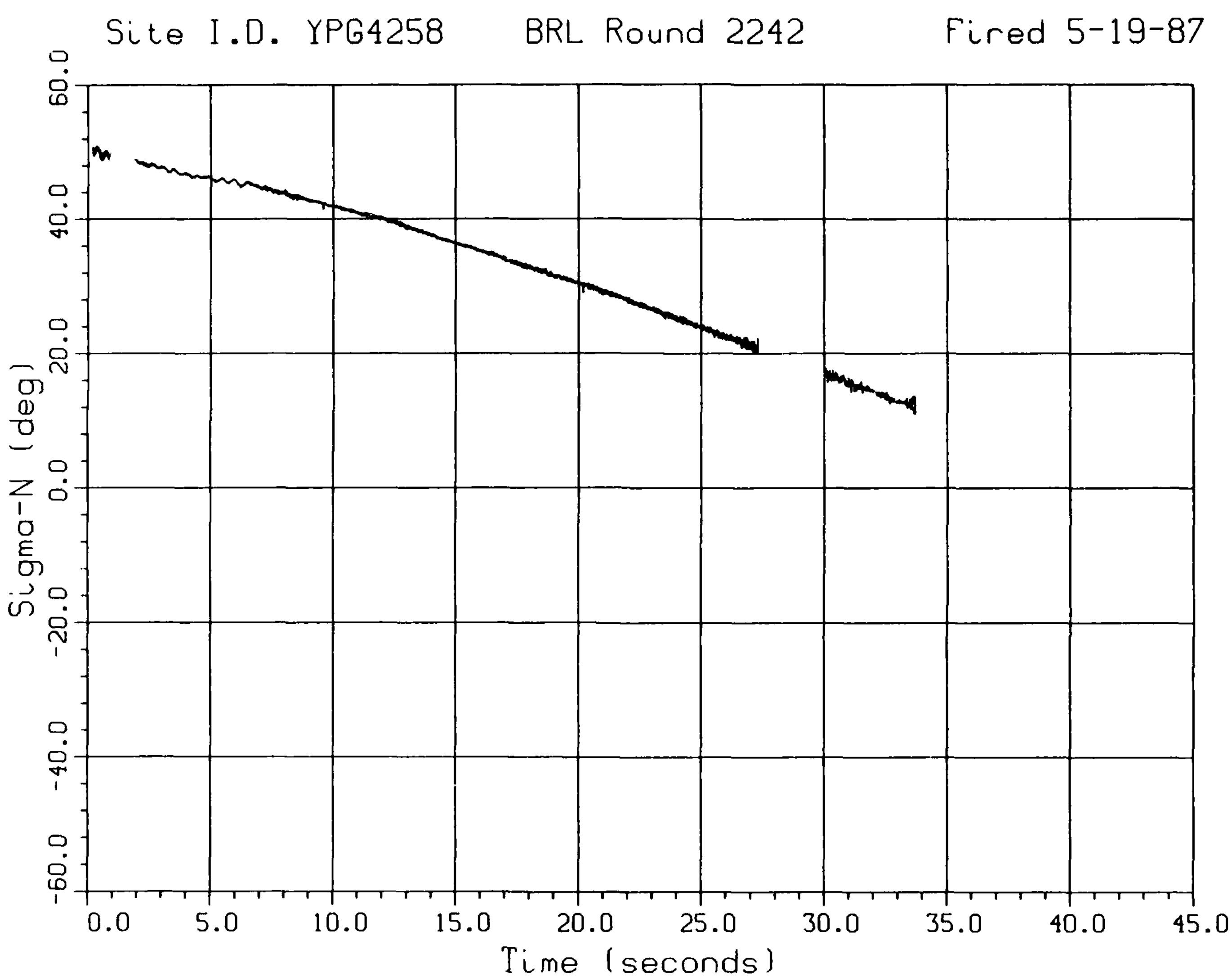

Figure 1. Yaw Angle Versus Time, Round 4258 (Yawsonde 2242)

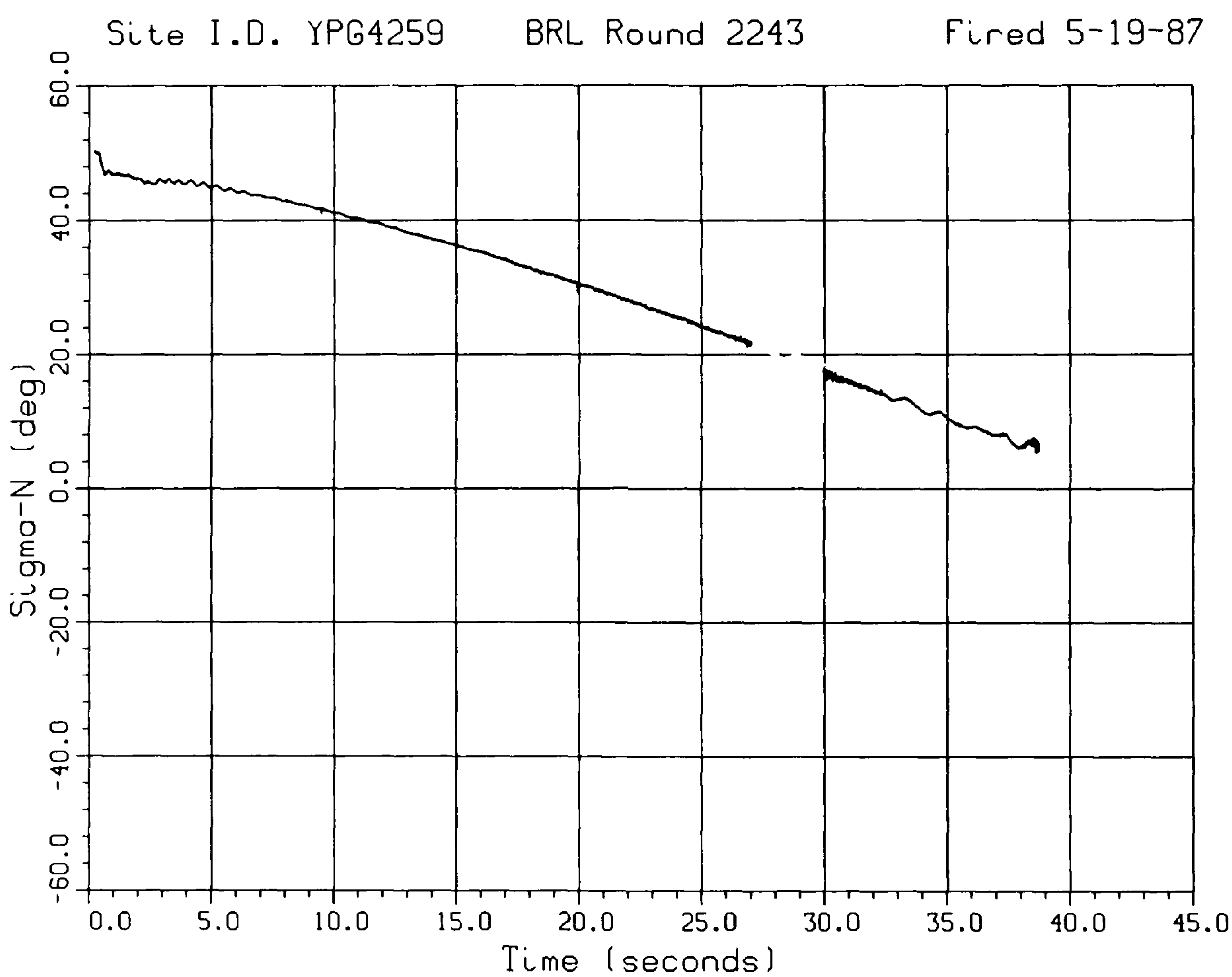

Figure 2a. Yaw Angle Versus Time, Round 4259 (Yawsonde 2243), 0-45 Seconds

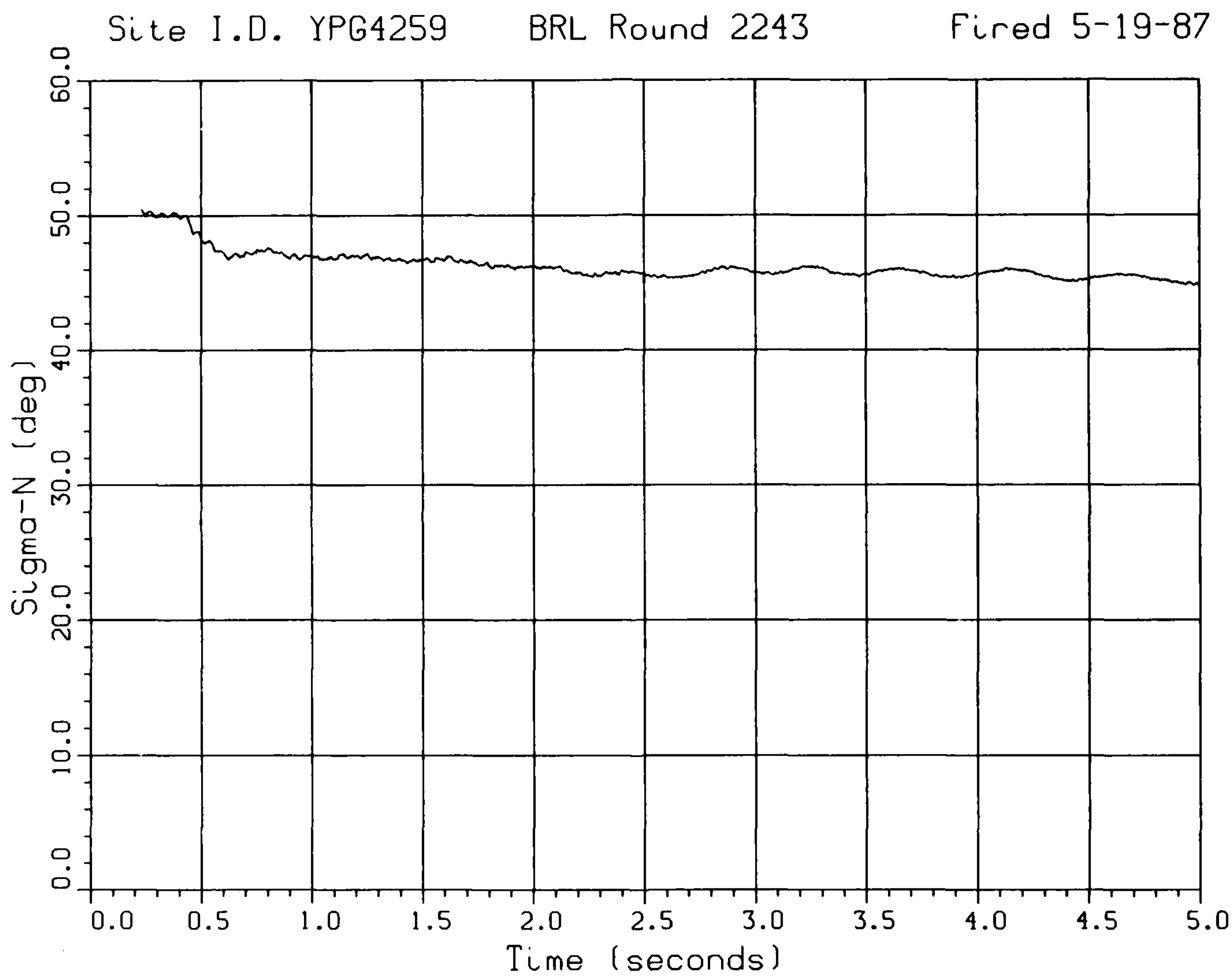

Figure 2b. Yaw Angle Versus Time, Round 4259 (Yawsonde 2243), 0-5 Seconds

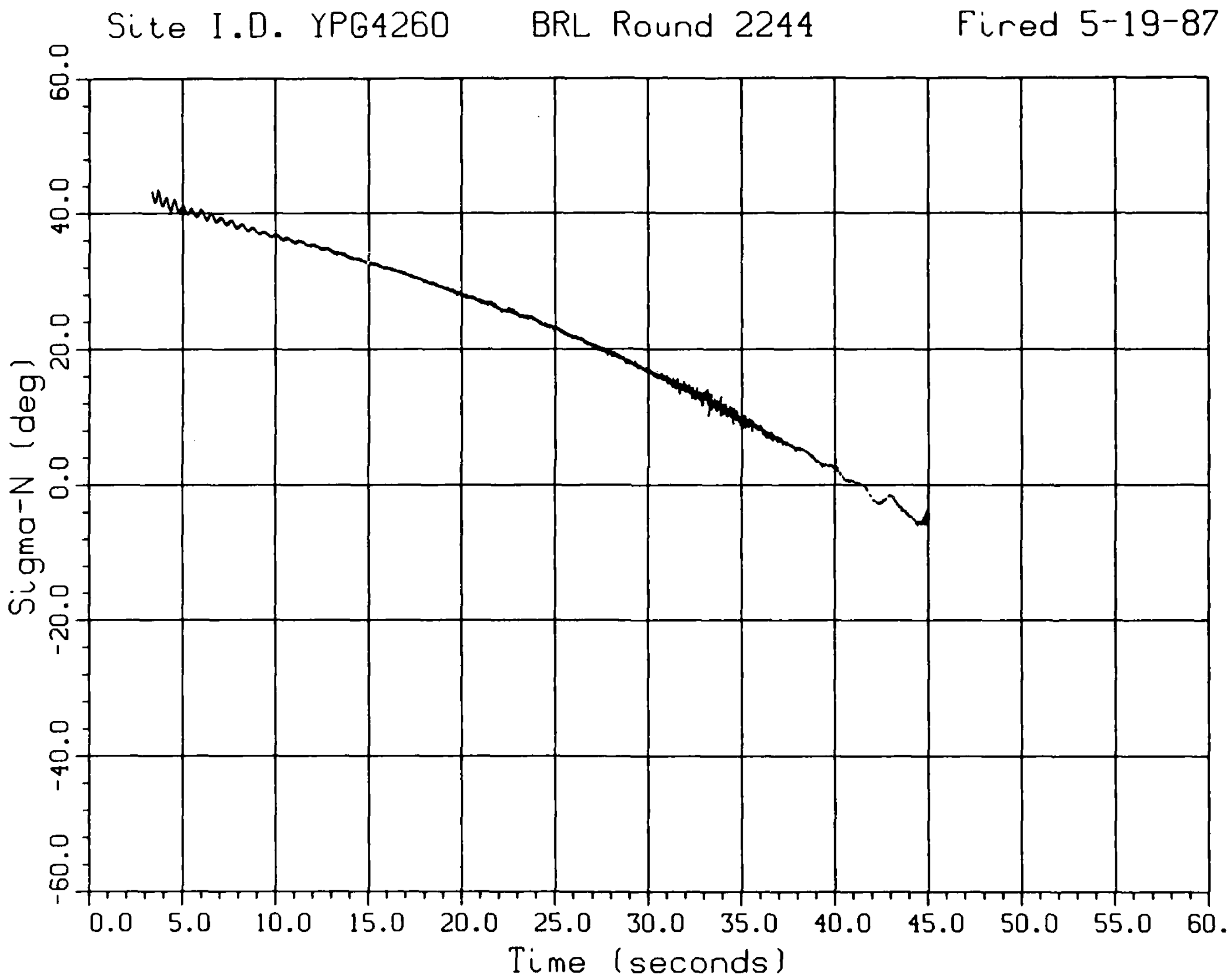

Figure 3. Yaw Angle Versus Time, Round 4260 (Yawsonde 2244)

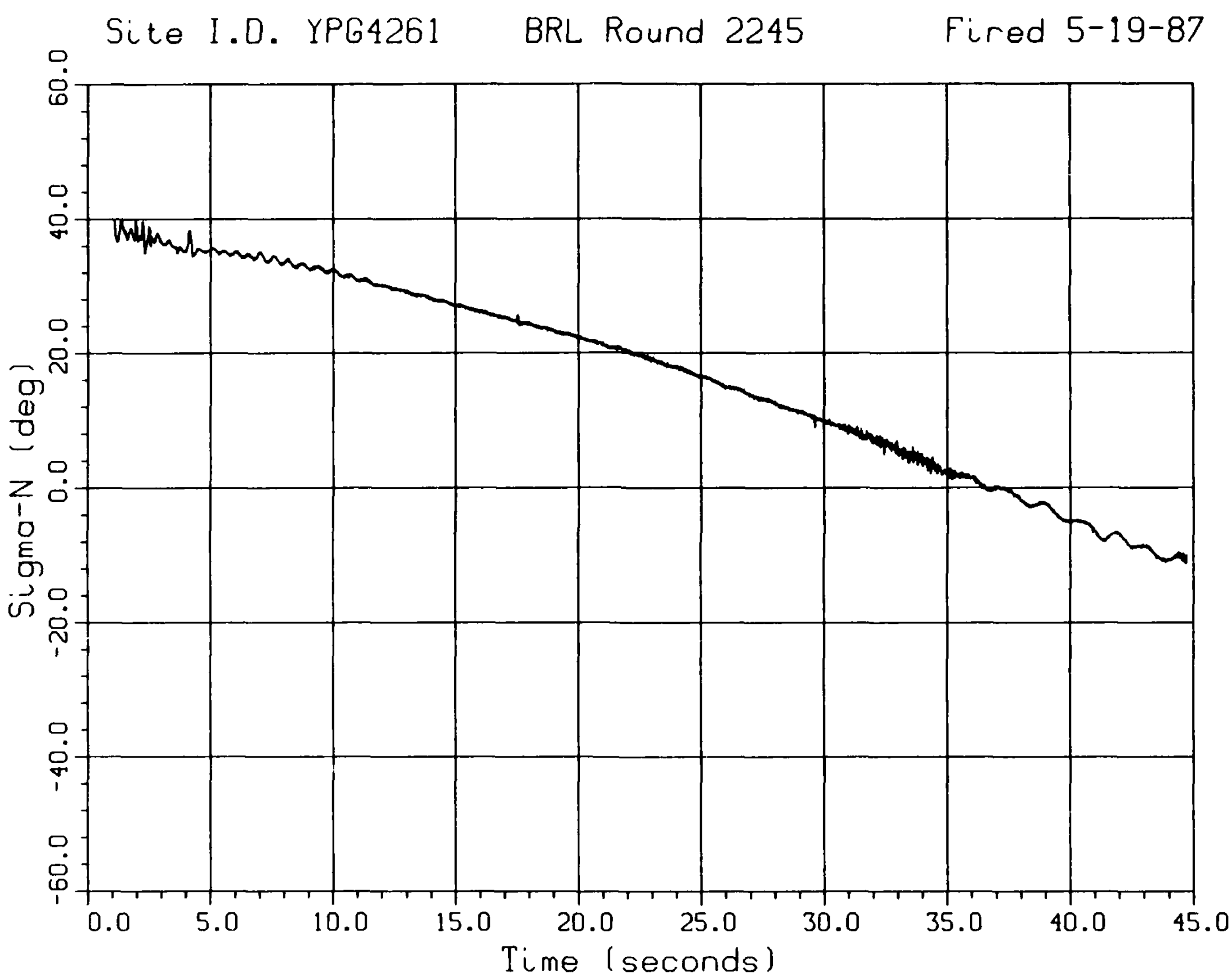

Figure 4a. Yaw Angle Versus Time, Round 4261 (Yawsonde 2245), 0-45 Seconds

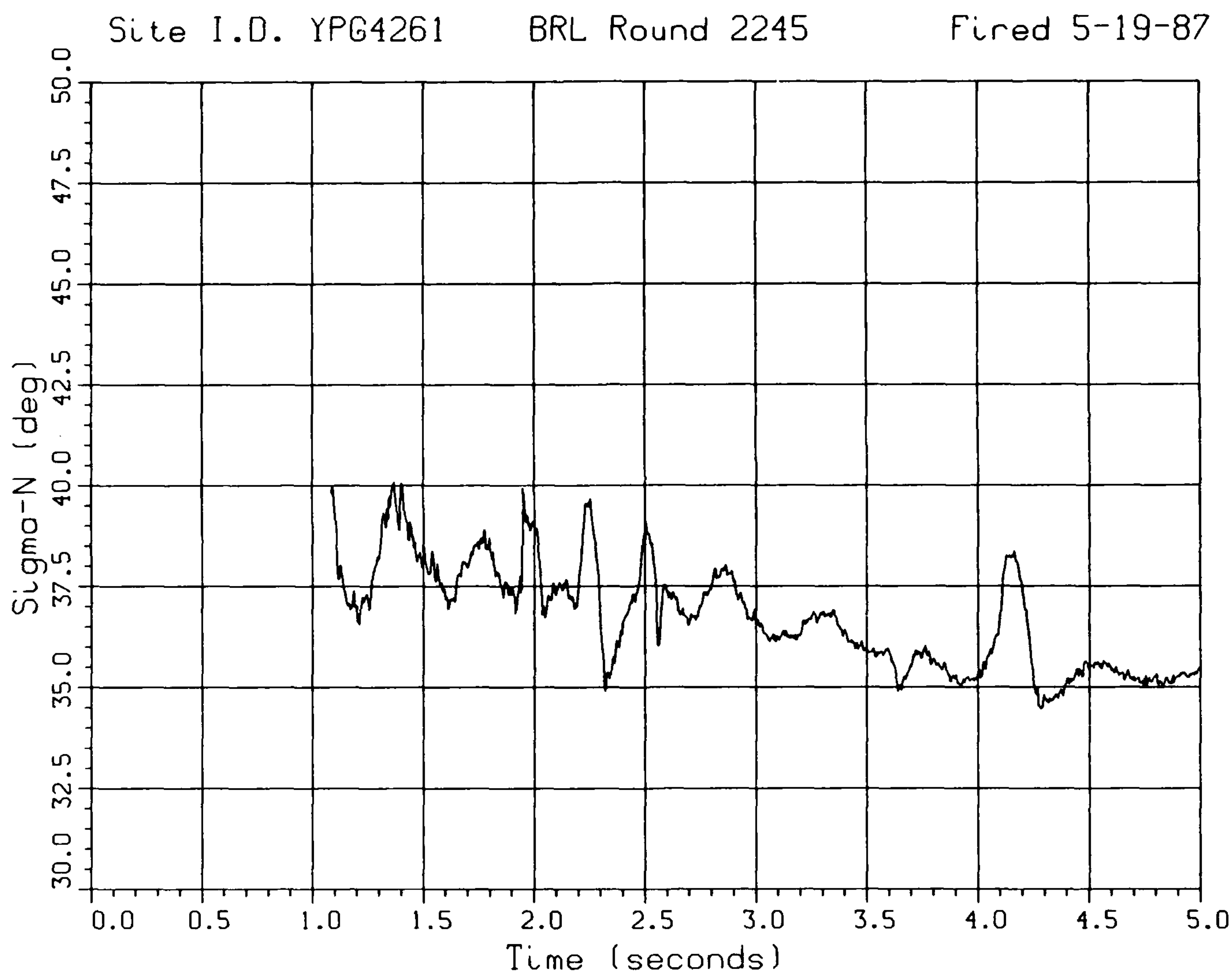

Figure 4b. Yaw Angle Versus Time, Round 4261 (Yawsonde 2245), 0-5 Seconds

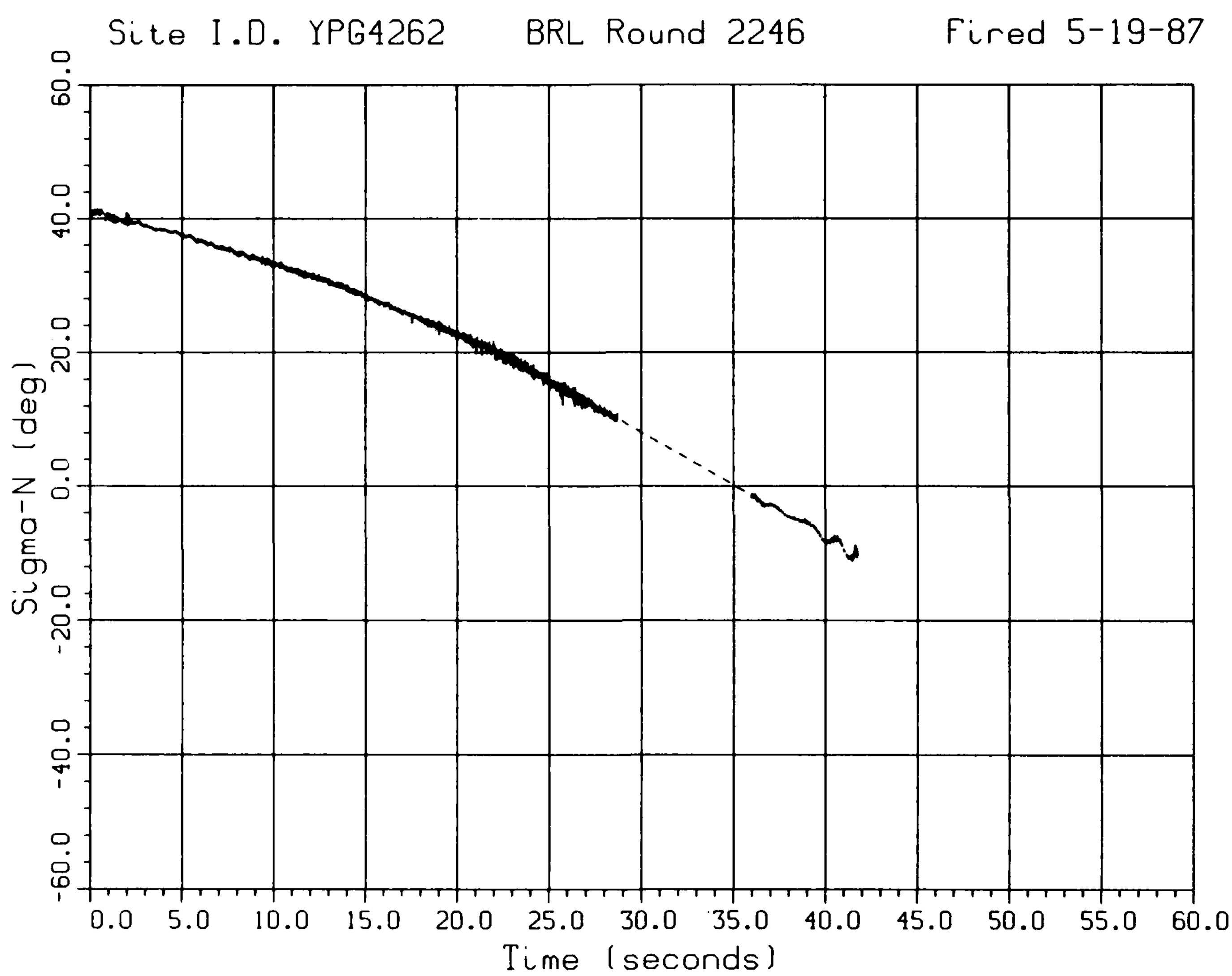

Figure 5. Yaw Angle Versus Time, Round 4262 (Yawsonde 2246)

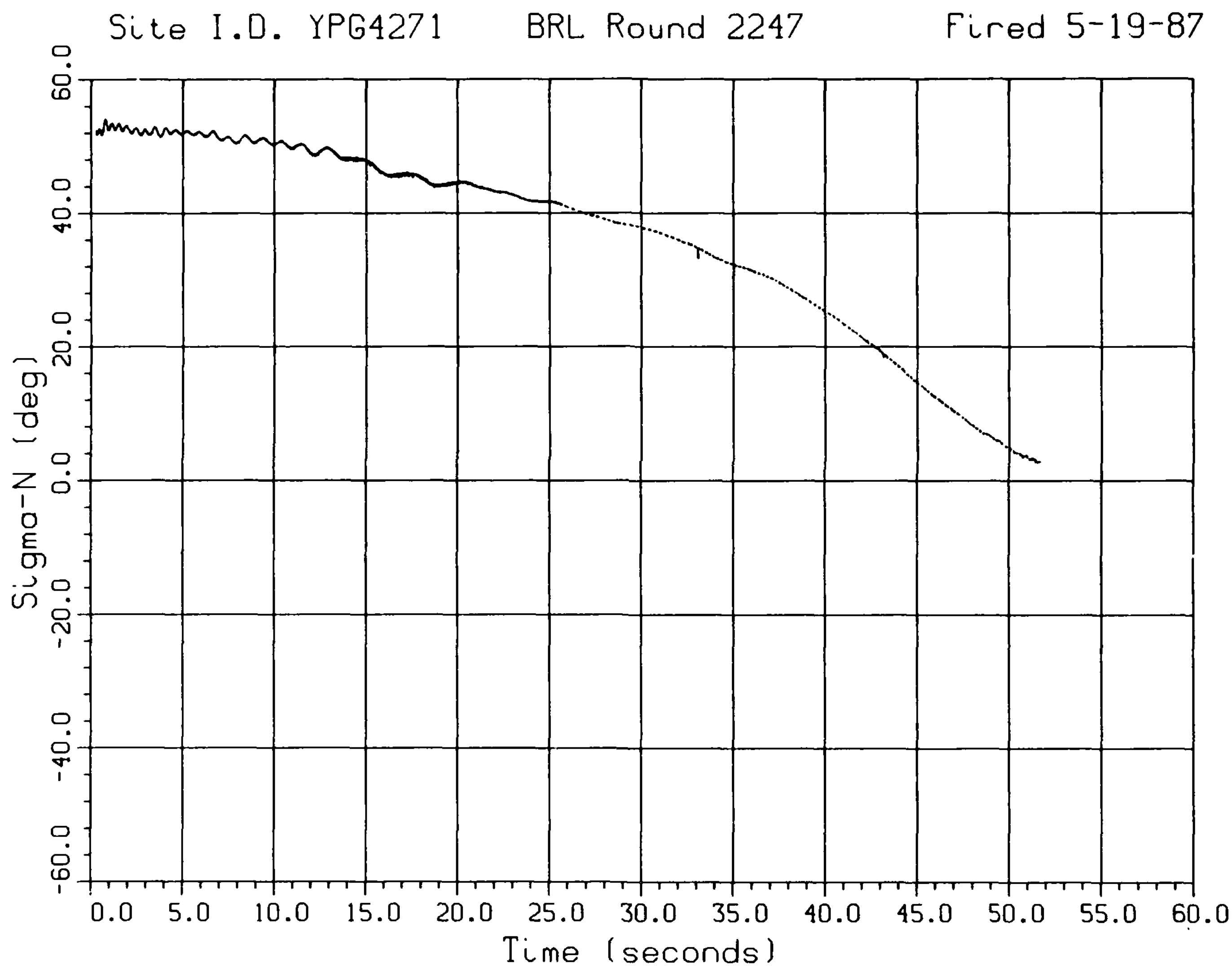

Figure 6. Yaw Angle Versus Time, Round 4271 (Yawsonde 2247)

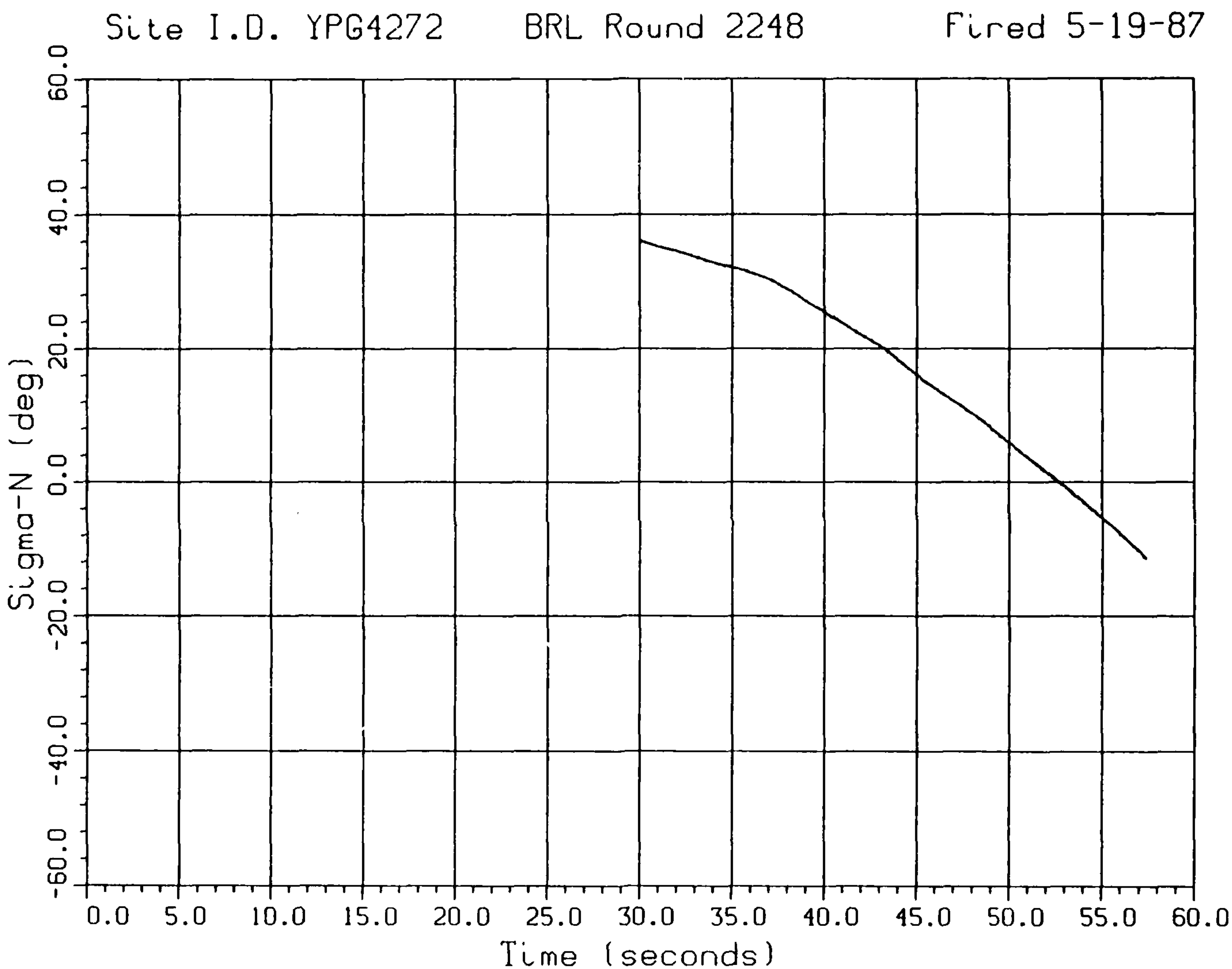

Figure 7. Yaw Angle Versus Time, Round 4272 (Yawsonde 2248)

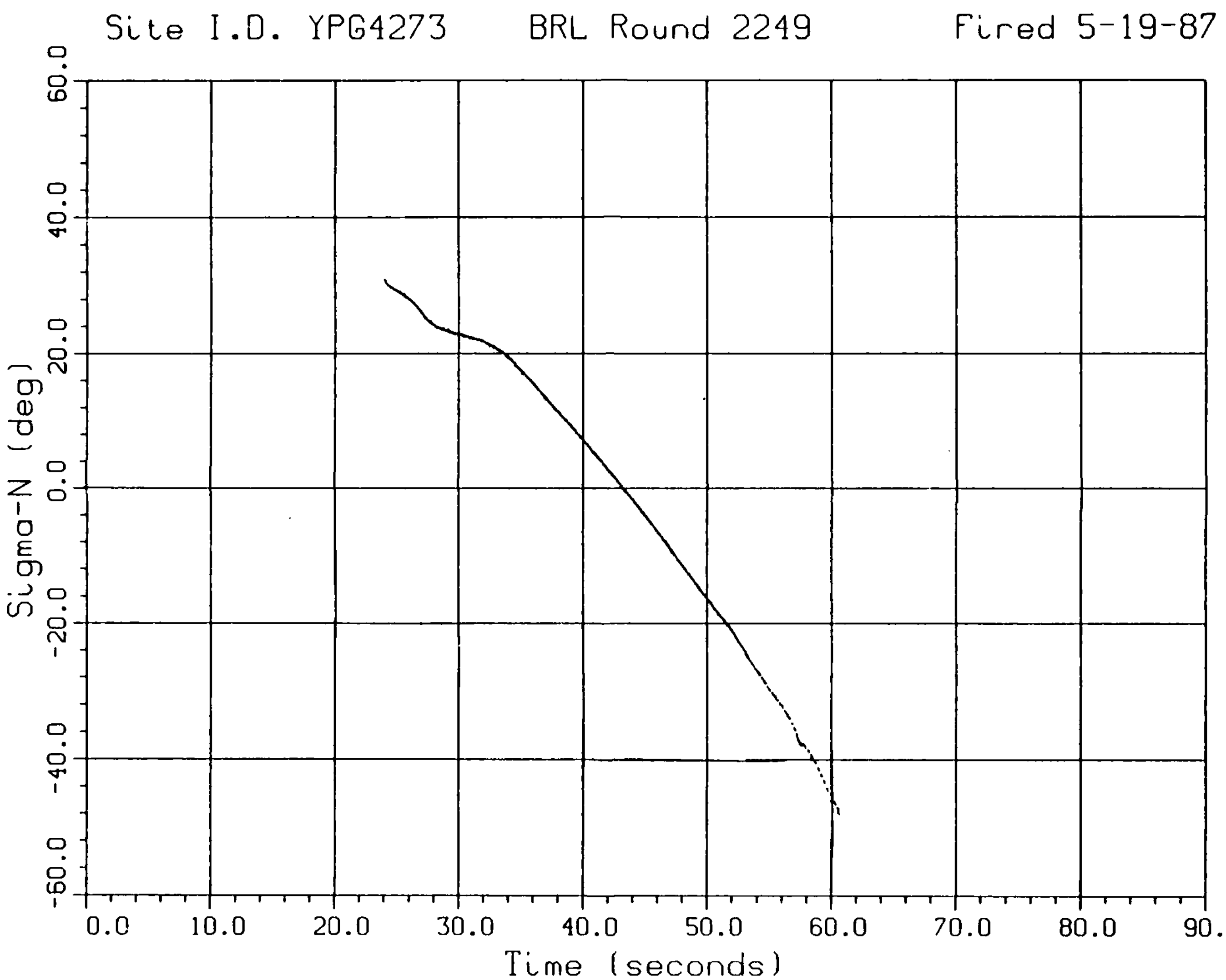

Figure 8. Yaw Angle Versus Time, Round 4273 (Yawsonde 2249)

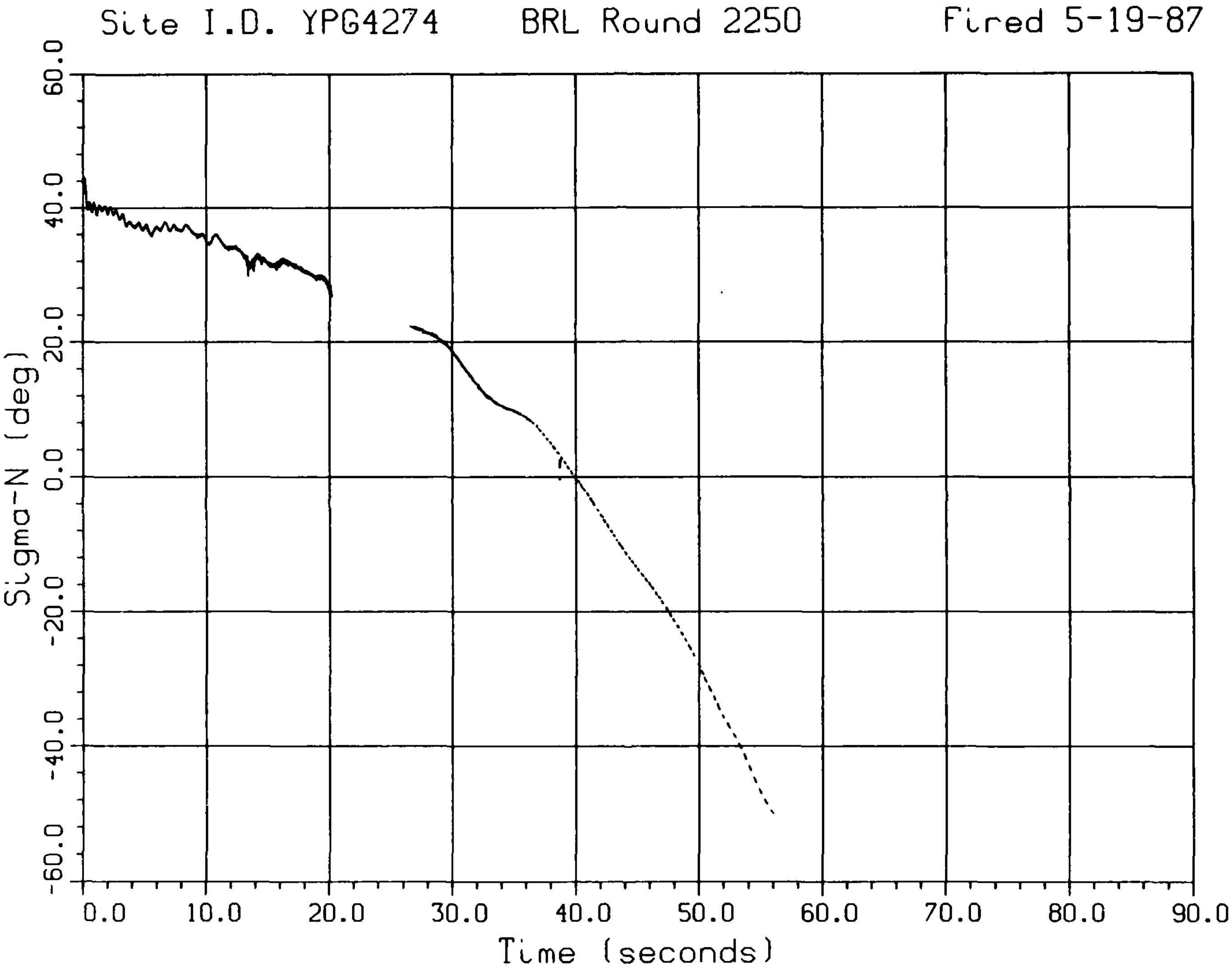

Figure 9. Yaw Angle Versus Time, Round 4274 (Yawsonde 2250)

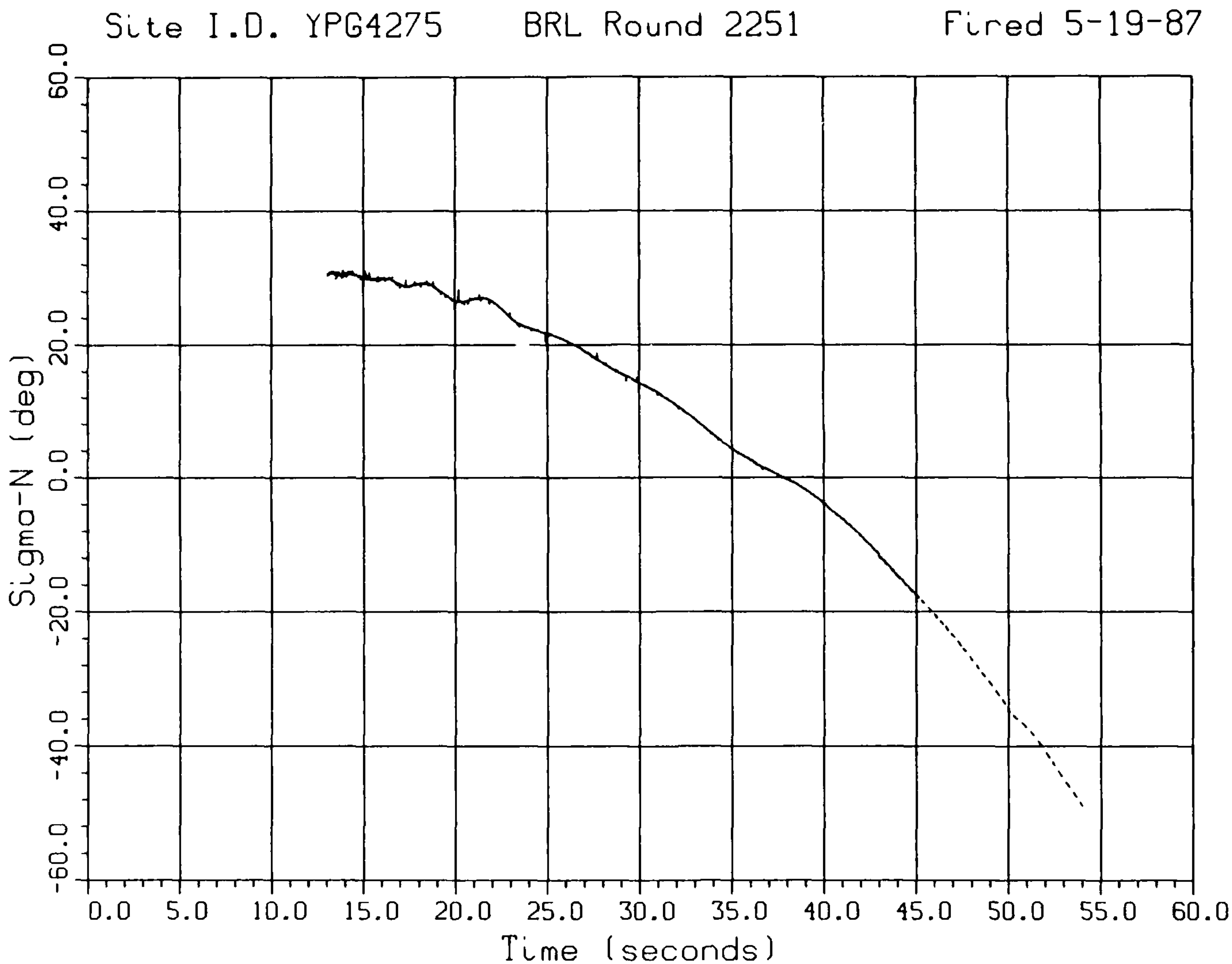

Figure 10. Yaw Angle Versus Time, Round 4275 (Yawsonde 2251)

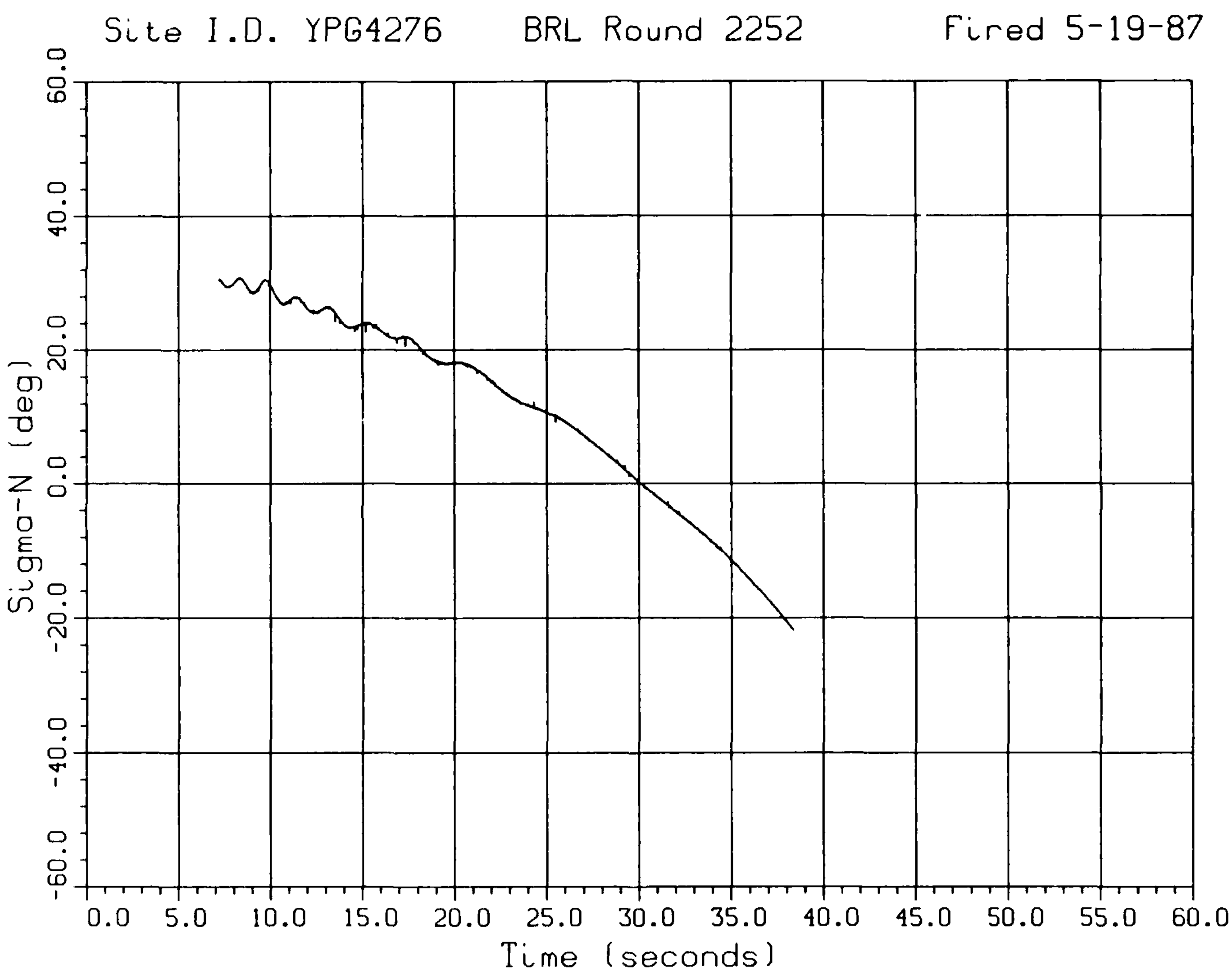

Figure 11. Yaw Angle Versus Time, Round 4276 (Yawsonde 2252)

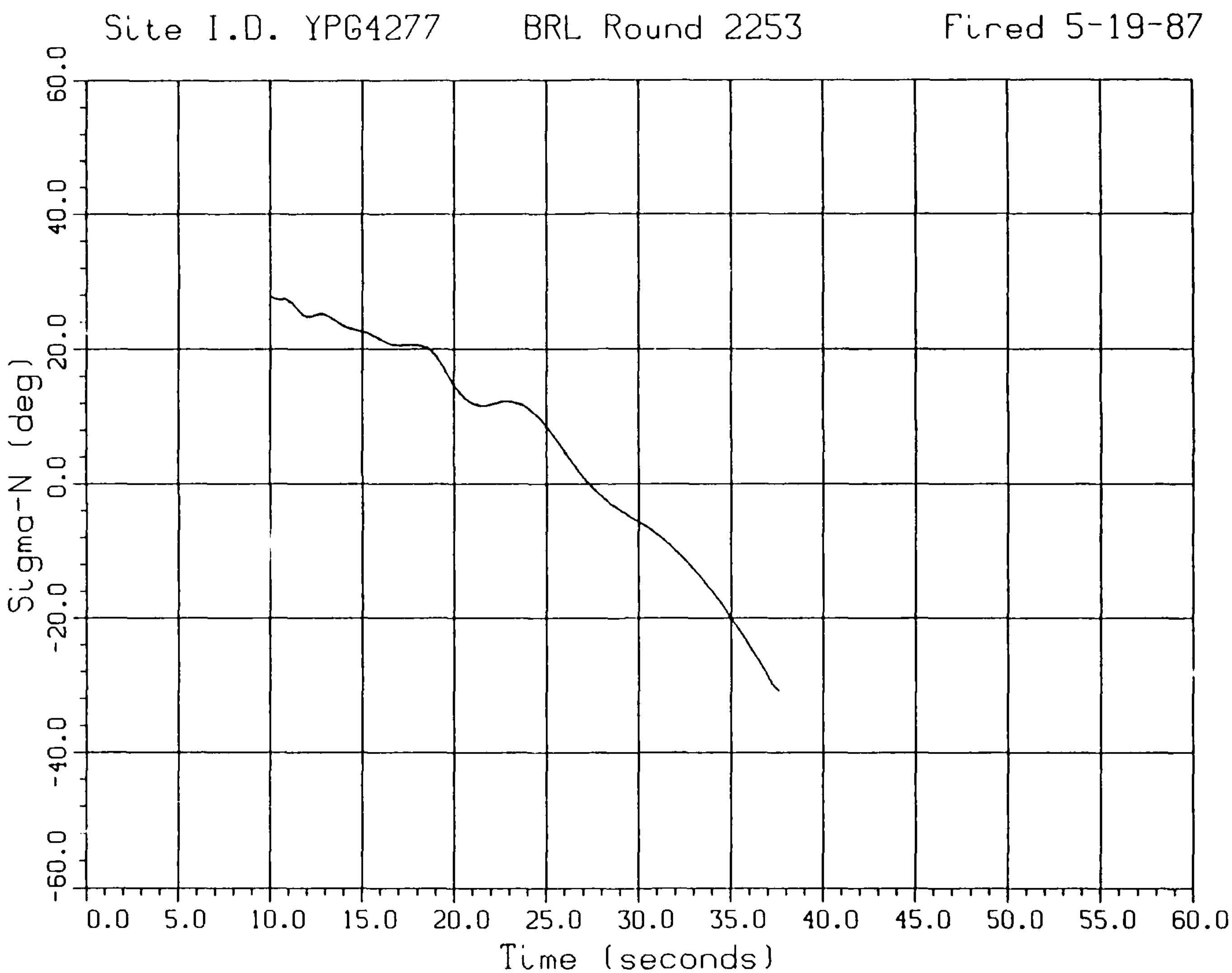

Figure 12. Yaw Angle Versus Time, Round 4277 (Yawsonde 2253)

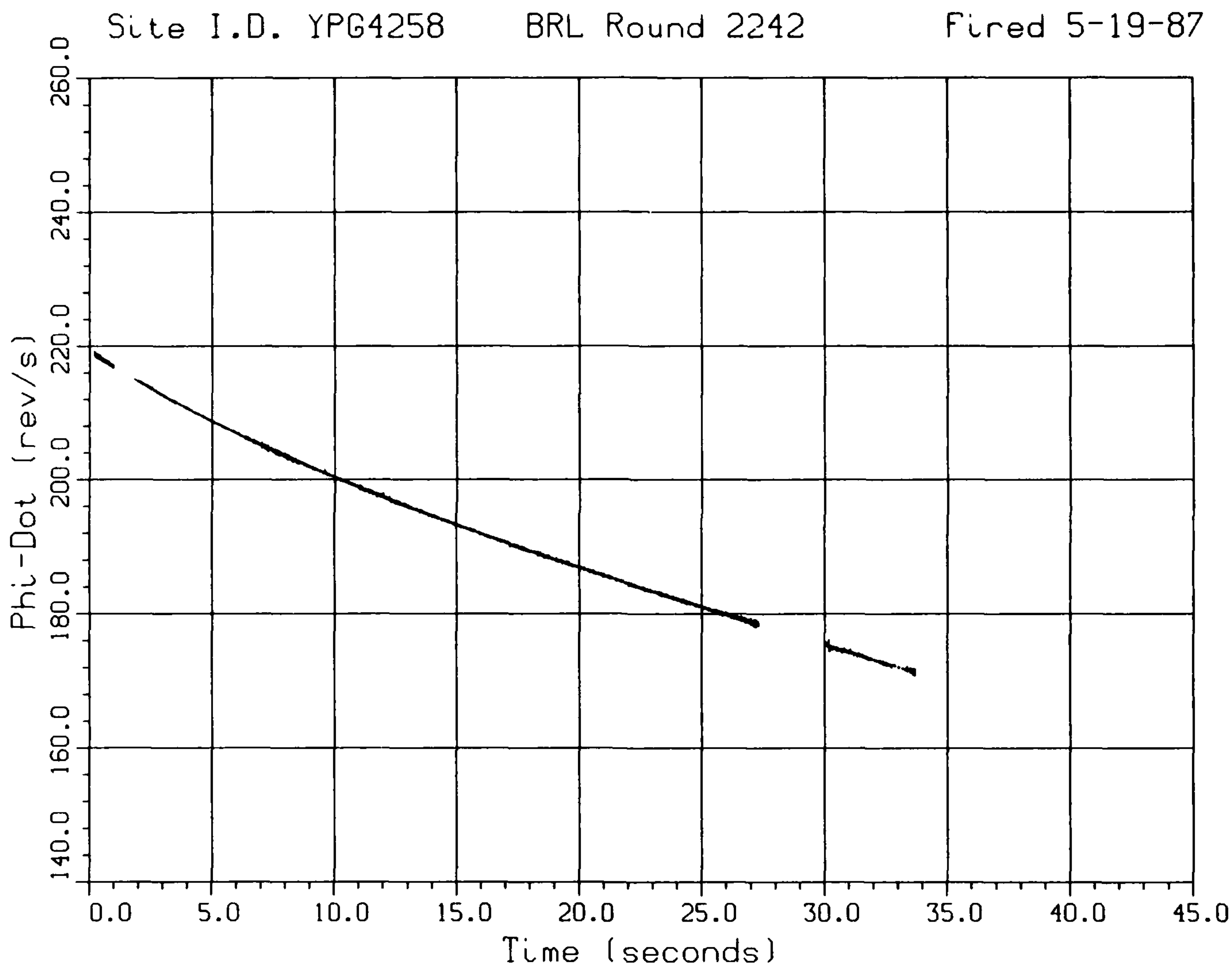

Figure 13. Spin Rate Versus Time, Round 4258 (Yawsonde 2242)

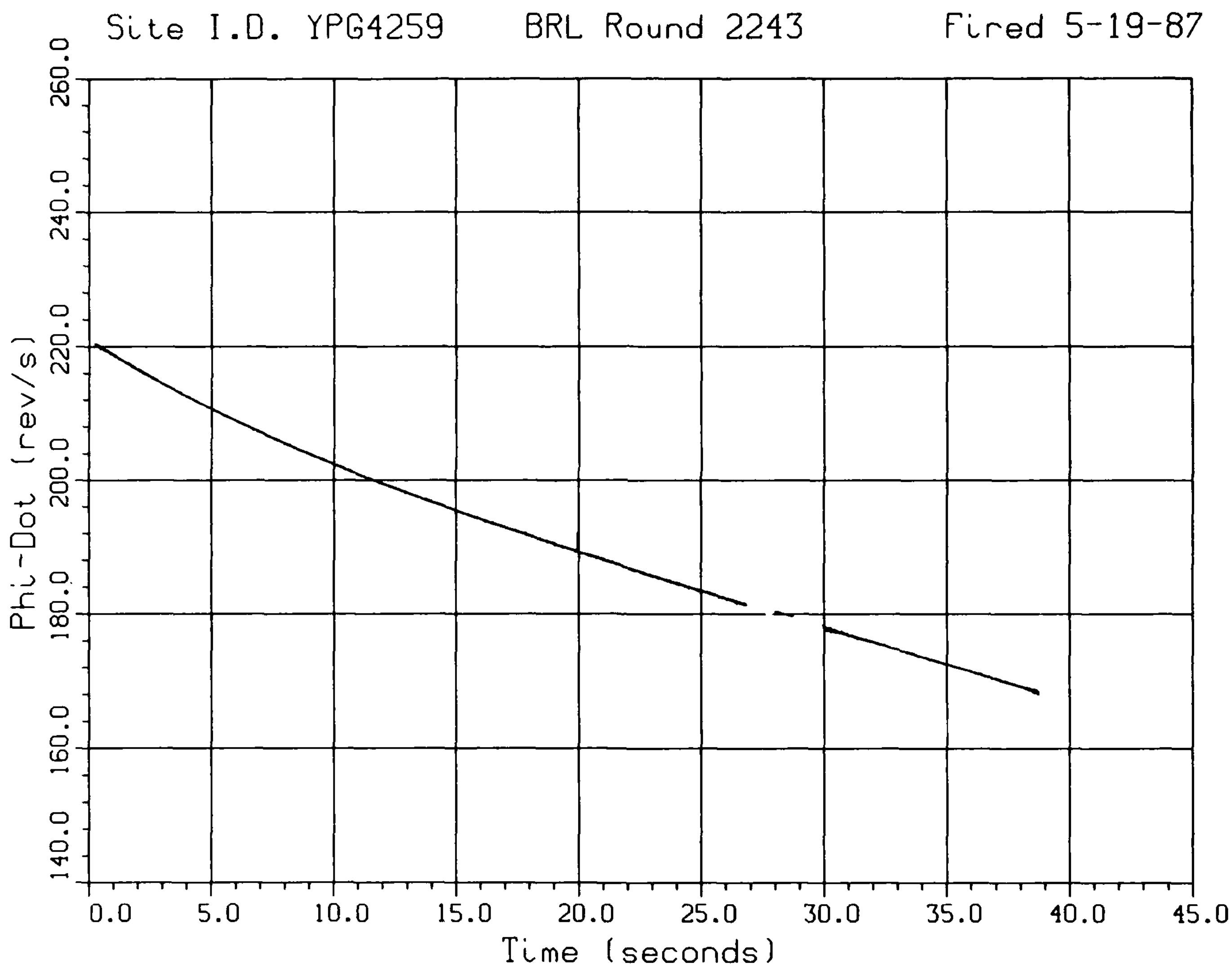

Figure 14. Spin Rate Versus Time, Round 4259 (Yawsonde 2243)

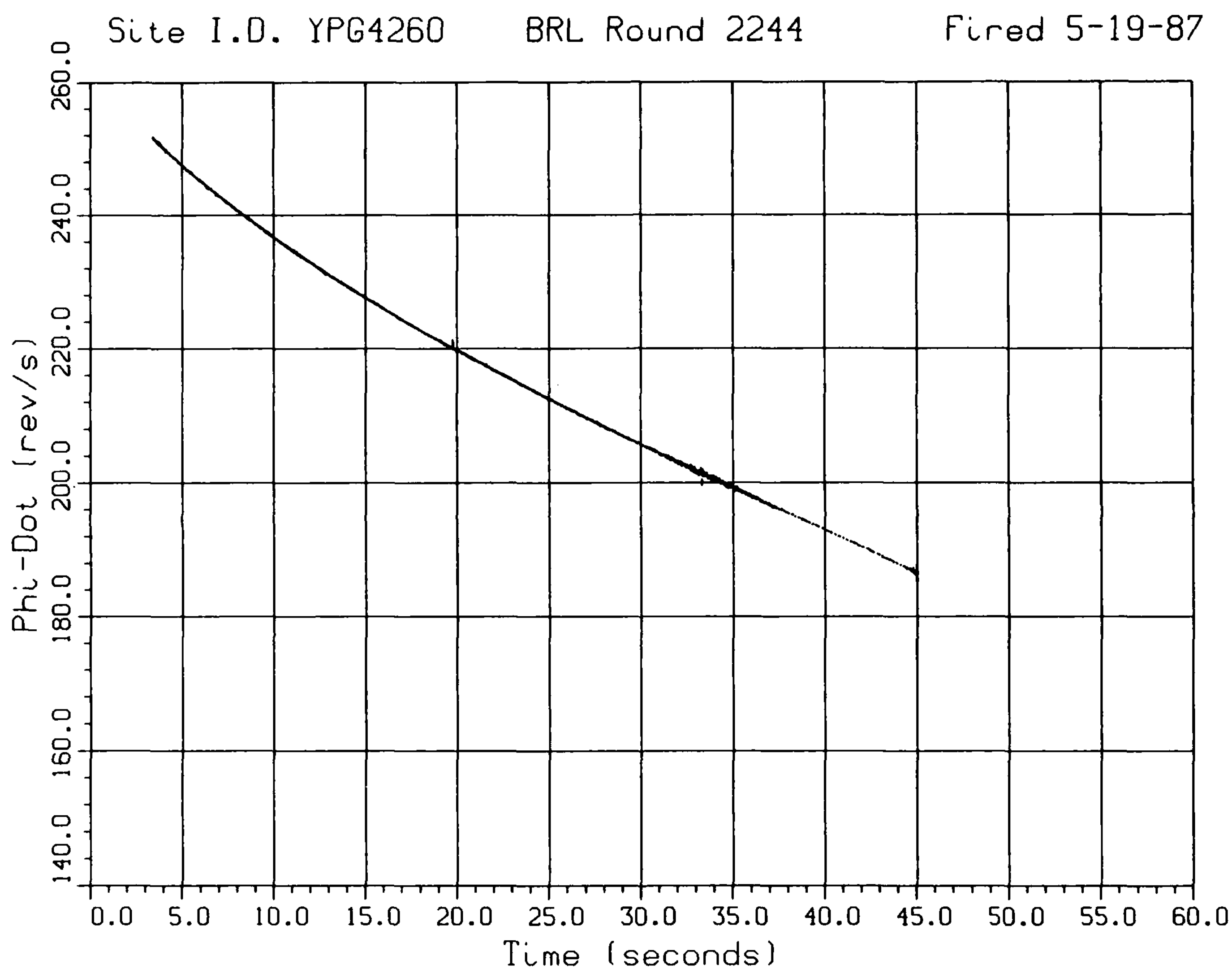

Figure 15. Spin Rate Versus Time, Round 4260 (Yawsonde 2244)

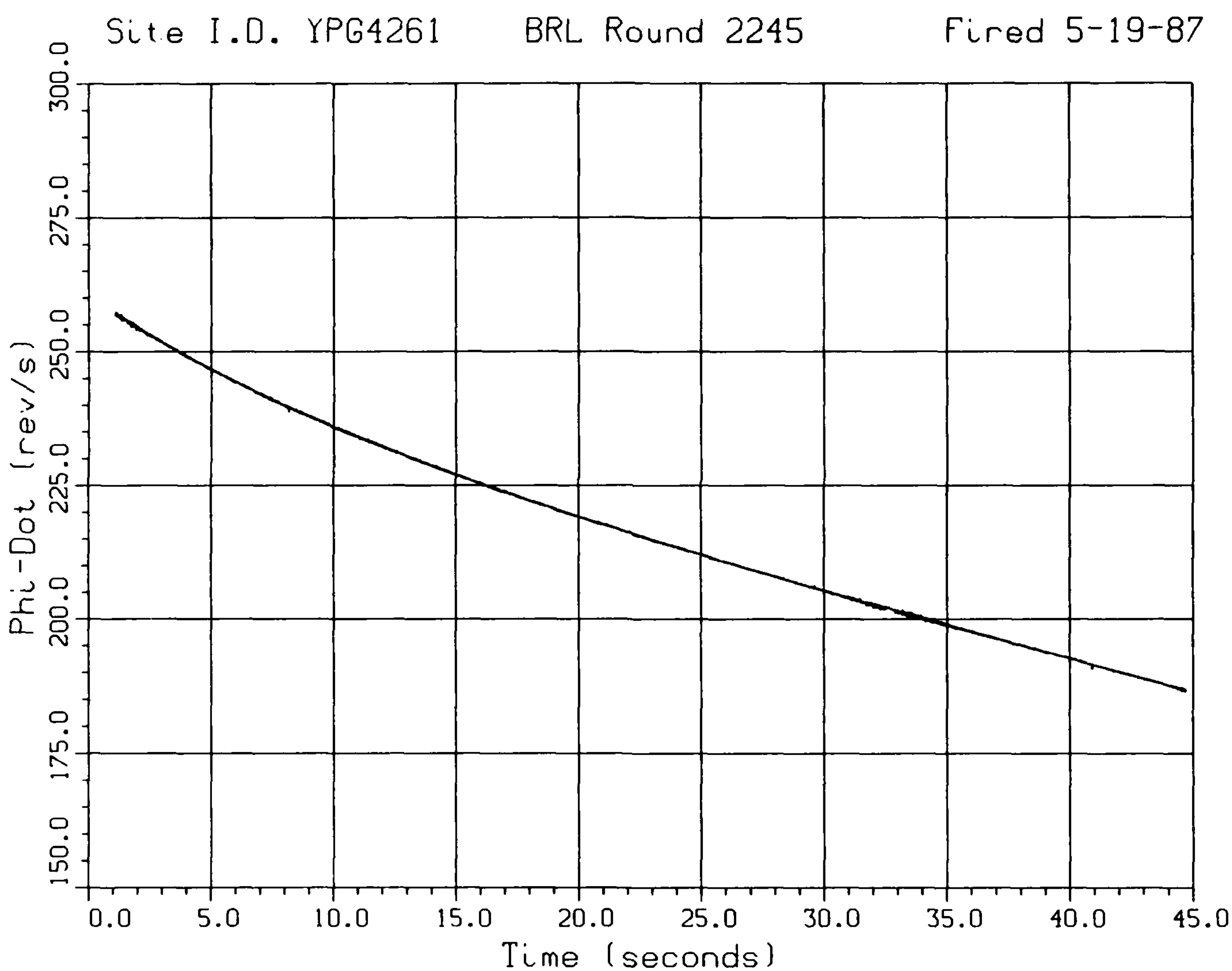

Figure 16. Spin Rate Versus Time, Round 4261 (Yawsonde 2245)

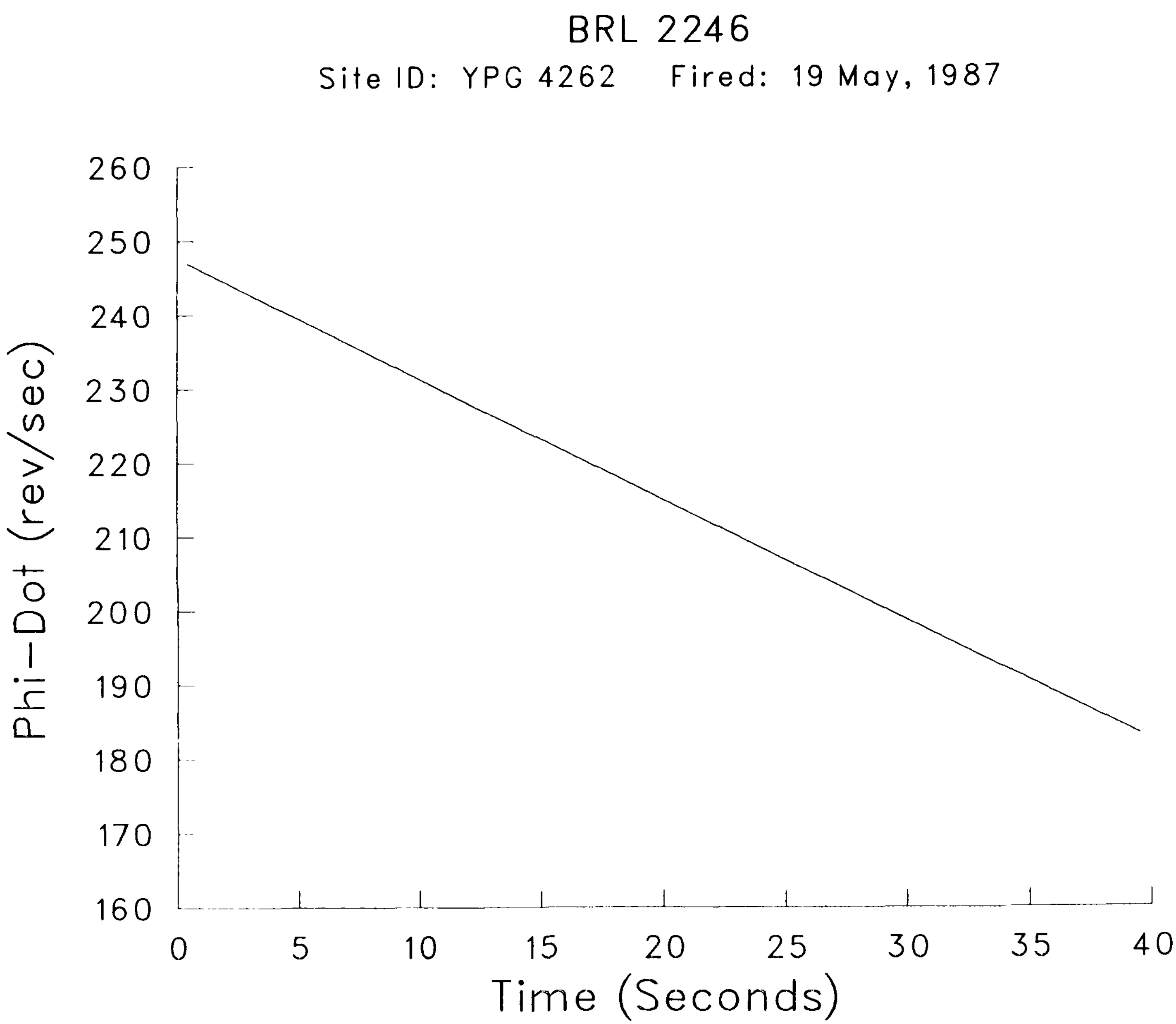

Figure 17. Spin Rate Versus Time, Round 4262 (Yawsonde 2246)

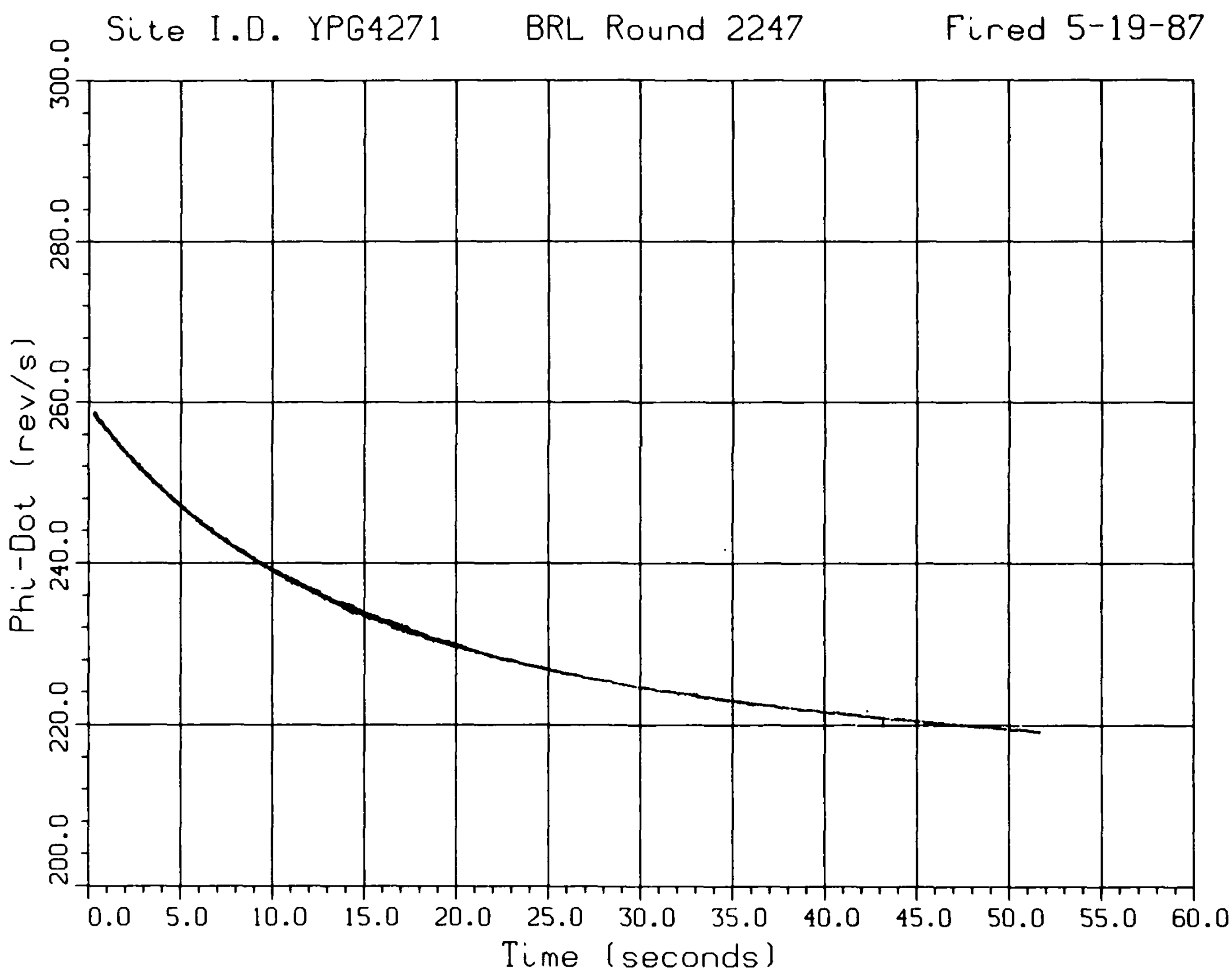

Figure 18. Spin Rate Versus Time, Round 4271 (Yawsonde 2247)

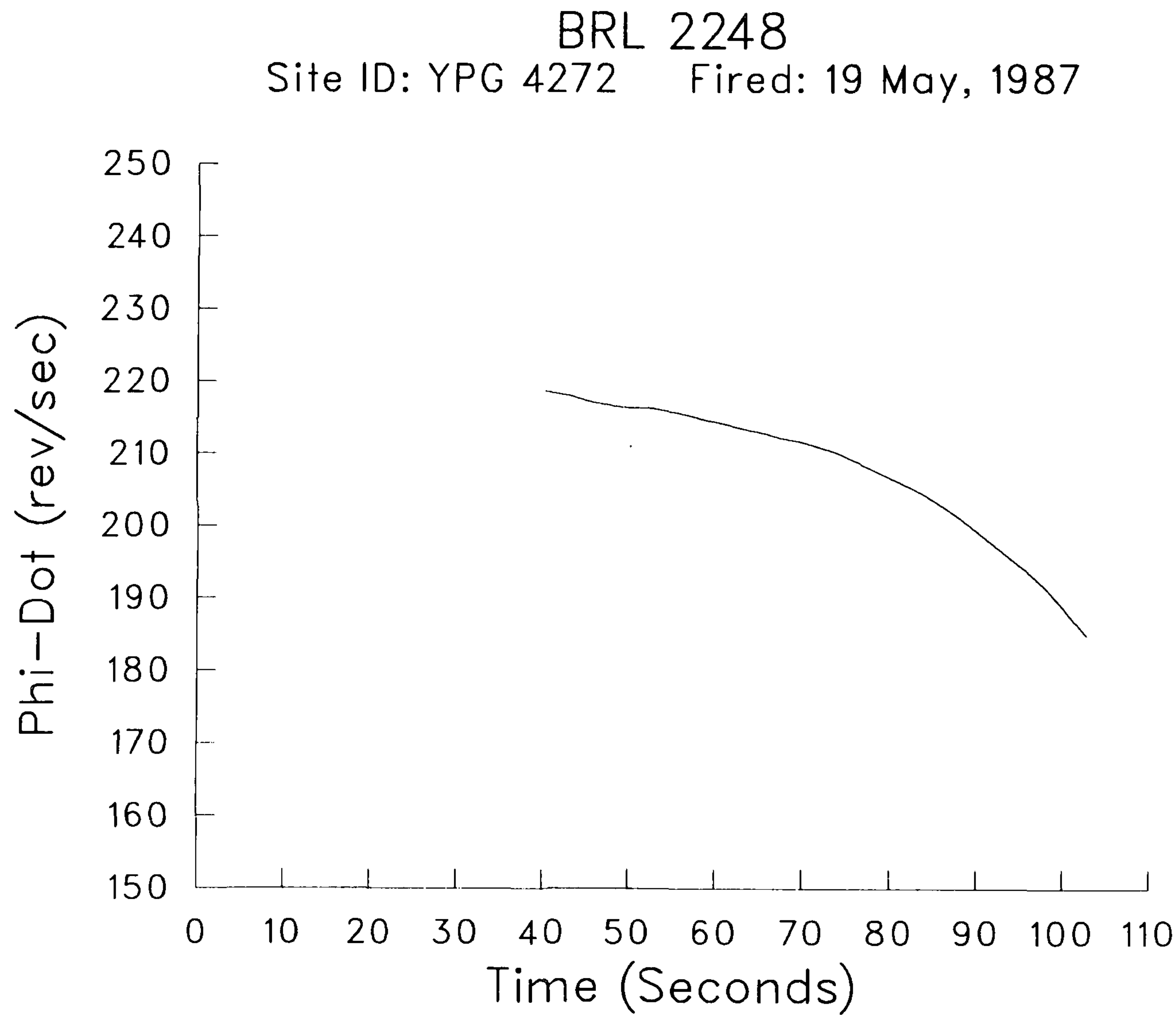

Figure 19. Spin Rate Versus Time, Round 4272 (Yawsonde 2248)

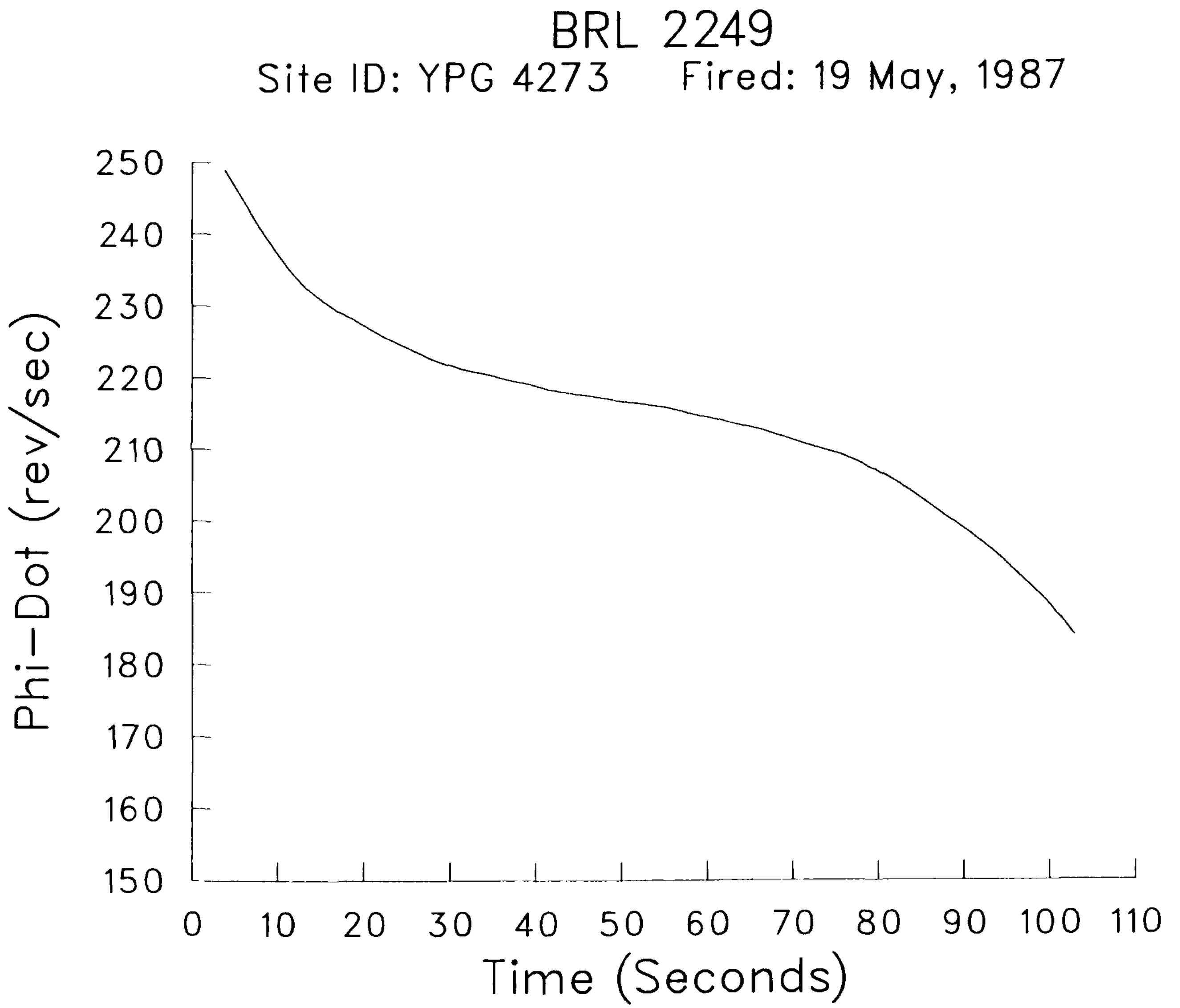

Figure 20. Spin Rate Versus Time, Round 4273 (Yawsonde 2249)

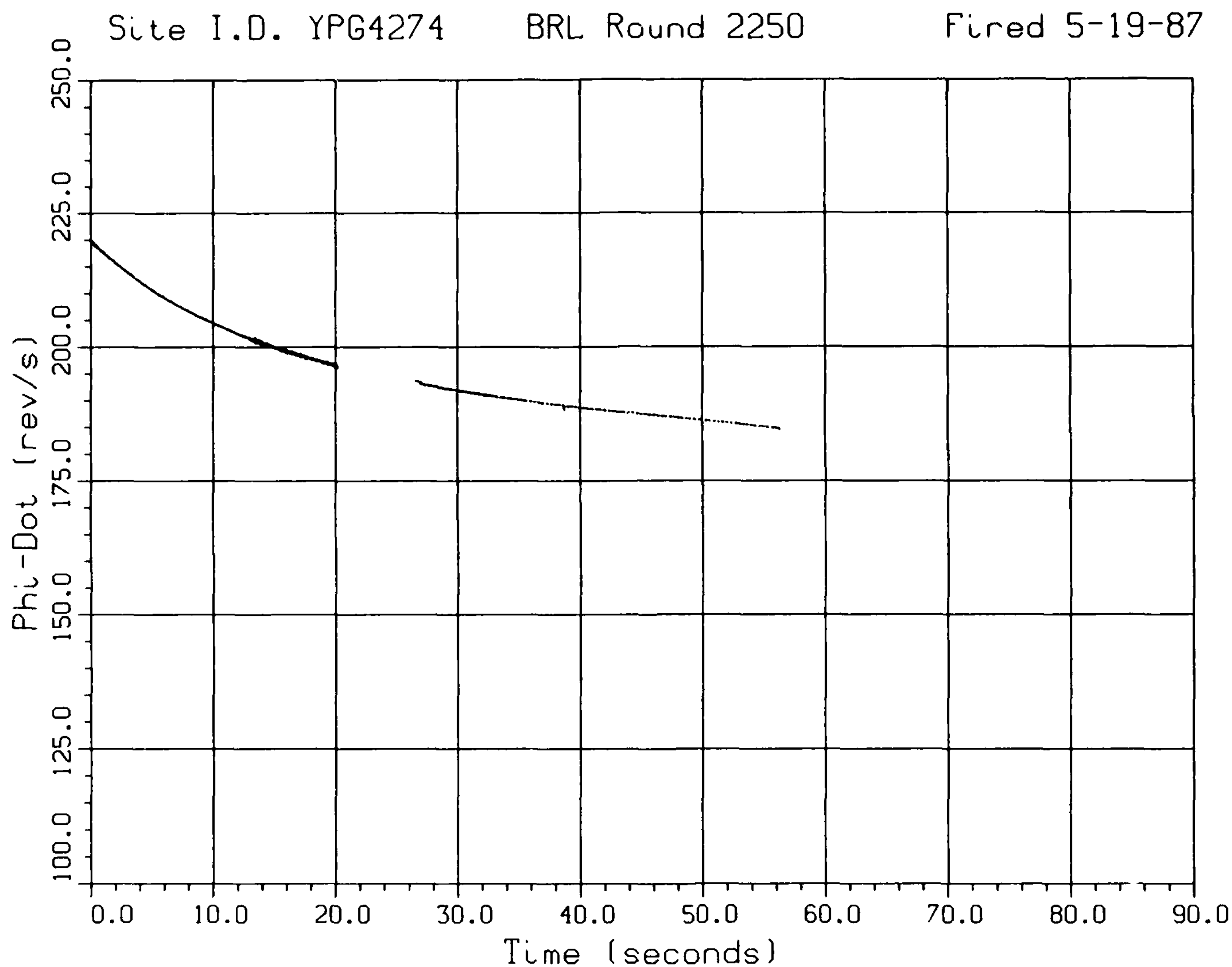

Figure 21. Spin Rate Versus Time, Round 4274 (Yawsonde 2250)

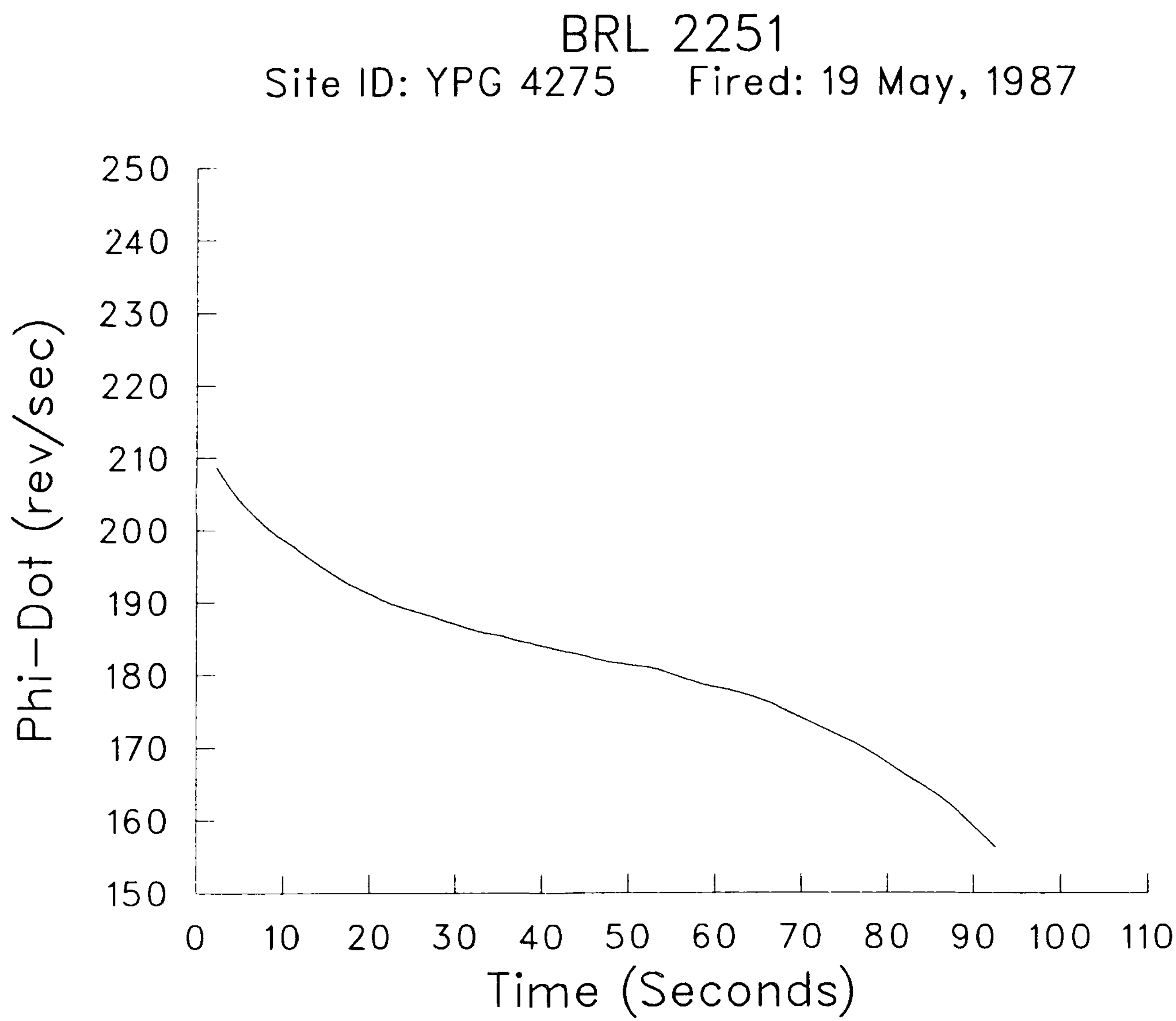

Figure 22. Spin Rate Versus Time, Round 4275 (Yawsonde 2251)

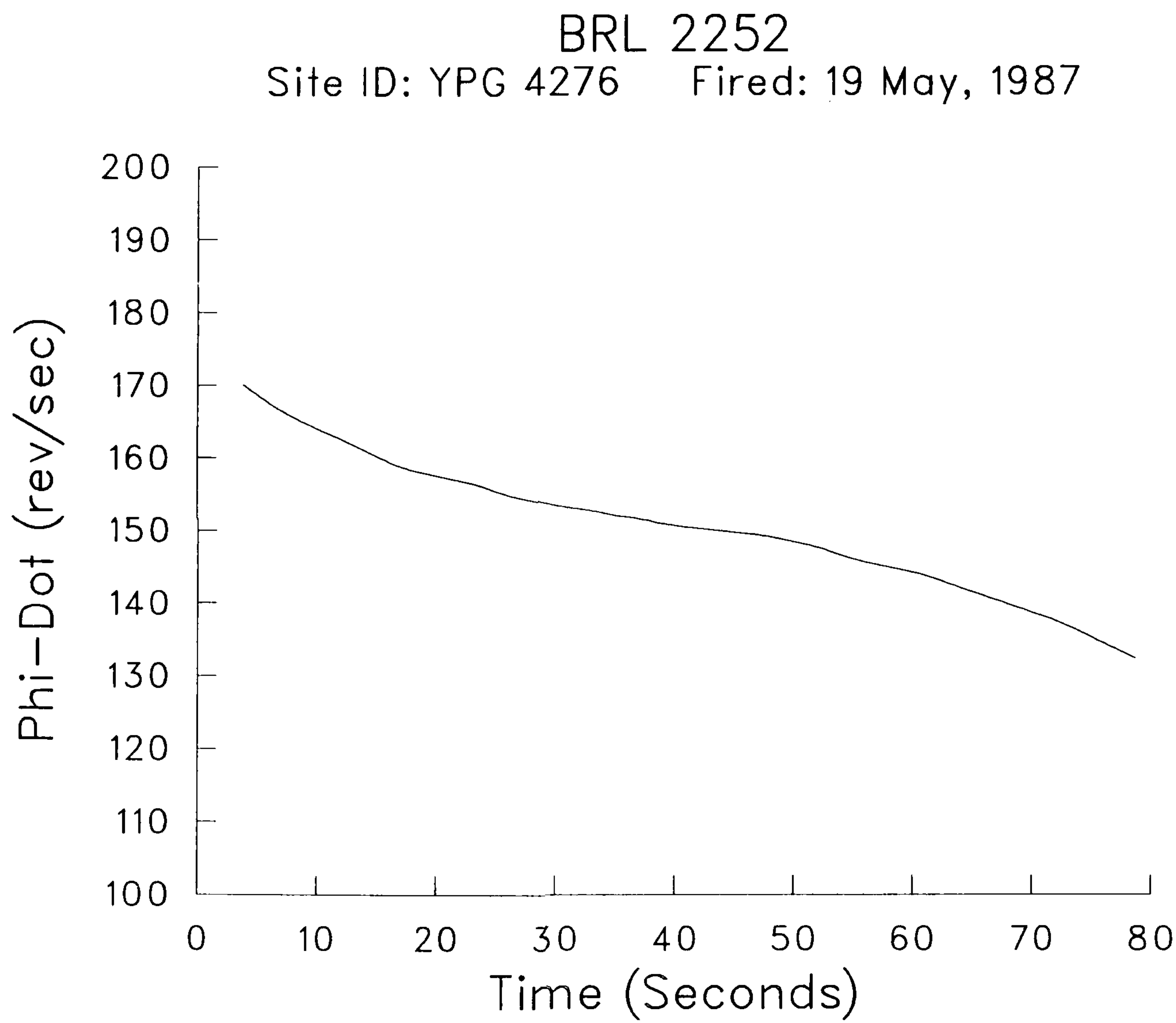

Figure 23. Spin Rate Versus Time, Round 4276 (Yawsonde 2252)

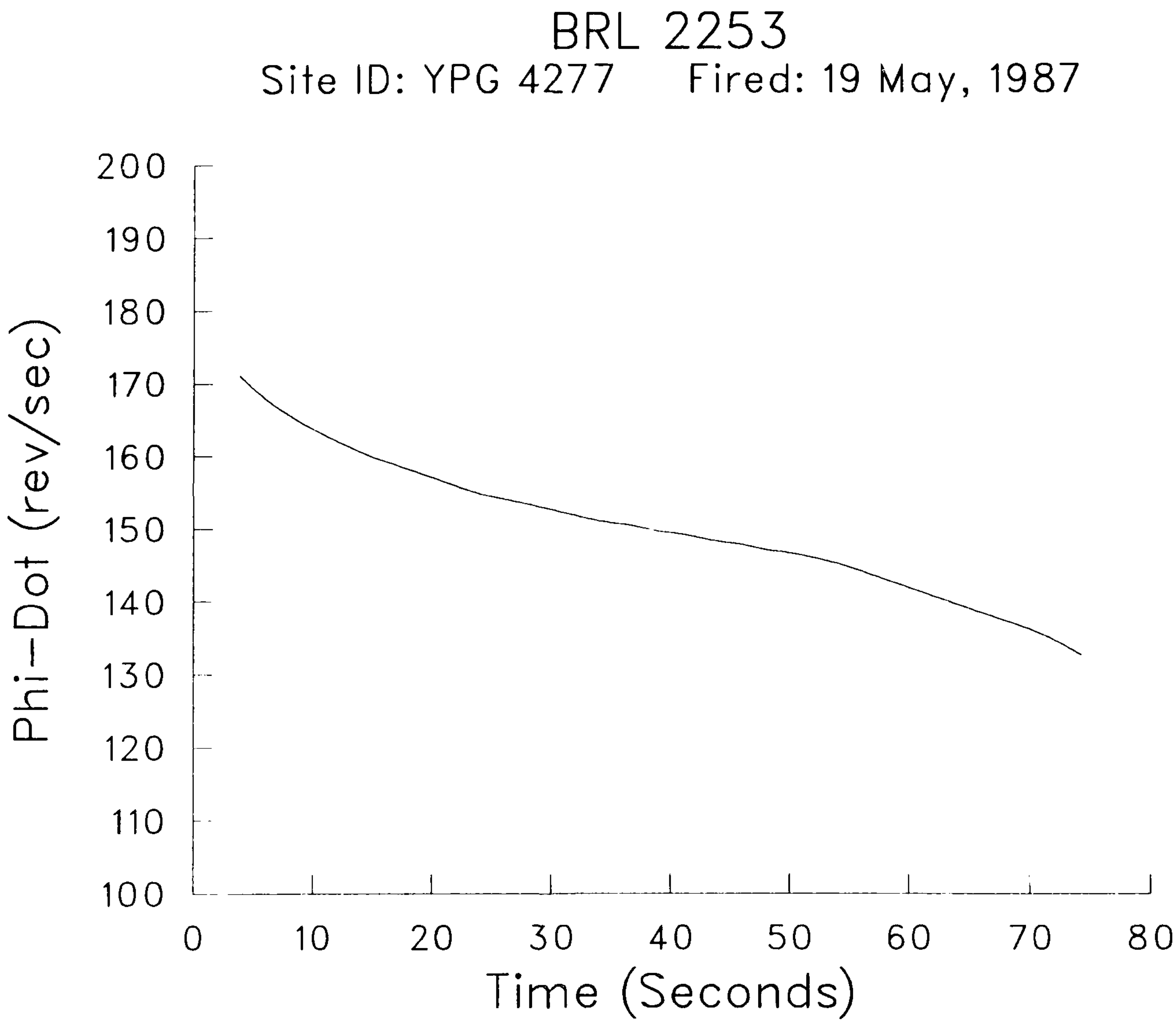

Figure 24. Spin Rate Versus Time, Round 4277 (Yawsonde 2253)

References

1. Test Program Request (TPR) (LCU-S-2973) Revision 1 to Amend. 2, Supl. 6 for Projectile, 155mm: Extended Range, DP, XM864 (TECOM Project No. 2-MU-003-864-003), ARDEC, Dover, New Jersey, 13 May 1987.
2. Mermagen, W. H. and Clay, W. H., "The Design of a Second Generation Yawsonde," MR 2368,, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, April 1974. (AD 780064)
3. Clay, W. H.,, "A Precision Yawsonde Calibration Technique," MR 2263, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, January 1973. (AD 758158)
4. Murphy, C. H., "Effects of Large High-Frequency Angular Motion of a Shell on the Analysis of Its Yawsonde Records," MR 2581, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, Maryland, February 1976. (AD 0094210)

DISTRIBUTION LIST

No. Copies	Organization
12	Administrator Defense Technical Information Center ATTN: DTIC-FDAC Cameron Station, Bldg. 5 Alexandria, VA 22304-6145
1	Commander US Army Material Command ATTN: AMCDRA-ST 5001 Eisenhower Avenue Alexandria, VA 22333-0001
1	Commander US Army ARDEC ATTN: SMCAR-TDC Dover, NJ 07801-5001
1	Commander U.S. Armament RD&E Center US Army AMCCOM ATTN: SMCAR-MSI Dover, NJ 07801-5001
1	Commander U.S. Armament RD&E Center US Army AMCCOM ATTN: SMCAR-LC Dover, NJ 07801-5001
1	OPM Nuclear ATTN: AMCPM-NUC COL. N. Barron Dover, NJ 07801-5001
1	Commander U.S. Army AMCCOM ATTN: SMCAR-CAWS-AM Dover, NJ 07801-5001
4	Commander U.S. Armament RD&E Center US Army AMCCOM ATTN: SMCAR-AET-A Mr. R. Kline Mr. H. Hudgins ATTN: SMCAR-LCU-SI Mr. F. Brody Mr. S. Harnett Dover, NJ 07801-5001
1	HQDA DAMA-ART-M Washington, DC 20310
1	Commander US Army Armament, Munitions and Chemical Command ATTN: AMSMC-IMP-L Rock Island, IL 61299-7300
1	Commander U.S. AMCCOM ARDEC CCAC Benet Weapons Laboratory ATTN: SMCAR-CCB-TL Watervliet, NY 12189-4050
1	Commander US Army Aviation Systems Command ATTN: AMSAV-ES 4300 Goodfellow Blvd St Louis, MO 63120-1789
1	Commander David W. Taylor Naval Ship Research and Development Center ATTN: Dr. Williams K. Blake Bethesda, MD 20084-5000

DISTRIBUTION LIST

No. Copies	Organization
1	Director US Army Aviation Research and Technology Activity Moffett Field, CA 94035-1099
1	Commander US Army Operations Test and Evaluation Agency ATTN: CSTE-TM-FA 5600 Columbia Pike Falls Church, VA 22041
1	Commander US Army Communications Electronics Command ATTN: AMSEL-ED Fort Monmouth, NJ 07703-5000
1	Commander CECOM R&D Technical Library ATTN: AMSEL-IM-L, (Reports Section) B. 2700 Fort Monmouth, NJ 07703-5000
10	C. I. A. OIC/DB/Standard GE47 HQ Washington, DC 20505
1	Commandant US Army Infantry School ATTN: ATSH-CD-CS-OR Fort Benning, GA 31905-5400
1	Commander US Army Missile Command Research Development and Engineering Center ATTN: AMSMI-RD Redstone Arsenal, AL 35898-5230
1	Commander US Army TRADOC ATTN: ATDC-F-A Fort Monroe, VA 23651
1	Commander US Army Missile Command ATTN: AMSMI-RDK, Mr. R. Deep Redstone Arsenal, AL 35898-5230
1	Director US Army Missile and Space Intelligence ATTN: AIAMS-YDL Redstone Arsenal, AL 35898-5500
1	Commander US Army Tank Automotive Command ATTN: AMSTA-TSL Warren, MI 48397-5000
1	AFWL/SUL Kirtland AFB, NM 87117-6008
1	Director US Army TRADOC Analysis Center ATTN: ATOR-TSL White Sands Missile Range NM 88002-5502
1	Commander US Army Development & Employment Agency ATTN: MODE-ORO Fort Lewis, WA 98433-5000
1	Commandant US Army Field Artillery School ATTN: ATSF-GD Fort Sills, OK 73503

DISTRIBUTION LIST

No. Copies	Organization	No. Copies	Organization
1	Commander US Army Dugway Proving Ground ATTN: STEDP-MT Mr. P. White Dugway, UT 84022	2	Rockwell International ATTN: Dr. V. Shankar Dr. S. Chakravarthy 1049 Camino Dos Rios Thousand Oaks, CA 91360
1	Commander US Army Yuma Proving Ground ATTN: STEYP-MTW Mr. J. Peters Yuma, AZ 85365-9103	1	Director US Army Field Artillery Board ATTN: ATZR-BDW Fort Sill, OK 73503
1	AFATL/DLODL Tech Info Center Eglin AFB, FL 32542-5438		**Aberdeen Proving Ground**
2	Raytheon Company Hartwell Road ATTN: Mr. V.A. Grosso Bedford. MA 01730		Director, USAMSAA ATTN: AMXSY-D AMXSY-RA Ms. J. Krolewski
1	Commander Naval Surface Weapons Center ATTN: Dr. W. Yanta Aerodynamics Branch K-24, Building 402-12 White Oak Laboratory Silver Spring, MD 20910		Commander, USATECOM ATTN: AMSTE-SI-F AMSTE-TE-F L. Neally W. Vomocil PM-SMOKE, Bldg. 324 ATTN: AMCPM-SMK-M Mr. J. Callahan ATTN: AMSTE-CM-F Mr. L Neally
1	Director National Aeronautics and Space Administration Ames Research Center ATTN: Dr. T. Steger Moffet Field, CA 94035		Cdr, CRDEC, AMCCOM ATTN: SMCCR-MU Mr. W. Dee Mr. C. Hughes ATTN: SMCCR-RSP-A Mr. Miles Miller ATTN: SMCCR-SPS-IL SMCCR-RSP-A SMCCR-MU
1	Calspan ATTN: W. Rae P.O. Box 400 Buffalo, NY 14225		

USER EVALUATION SHEET/CHANGE OF ADDRESS

This Laboratory undertakes a continuing effort to improve the quality of the reports it publishes. Your comments/answers to the items/questions below will aid us in our efforts.

1. BRL Report Number____________________Date of Report__________

2. Date Report Received__________________________________

3. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which the report will be used.)__________

4. How specifically, is the report being used? (Information source, design data, procedure, source of ideas, etc.)__________

5. Has the information in this report led to any quantitative savings as far as man-hours or dollars saved, operating costs avoided or efficiencies achieved, etc? If so, please elaborate.__________

6. General Comments. What do you think should be changed to improve future reports? (Indicate changes to organization, technical content, format, etc.)

CURRENT ADDRESS

Name

Organization

Address

City, State, Zip

7. If indicating a Change of Address or Address Correction, please provide the New or Correct Address in Block 6 above and the Old or Incorrect address below.

OLD ADDRESS

Name

Organization

Address

City, State, Zip

(Remove this sheet, fold as indicated, staple or tape closed, and mail.)

FOLD HERE

Director
U.S. Army Ballistic Research Laboratory
ATTN: SLCBR-DD-T
Aberdeen Proving Ground, MD 21005-5066

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE. $300

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO 12062 WASHINGTON,DC
POSTAGE WILL BE PAID BY DEPARTMENT OF THE ARMY

Director
U.S. Army Ballistic Research Laboratory
ATTN: SLCBR-DD-T
Aberdeen Proving Ground, MD 21005-9989

FOLD HERE